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the flow of tissue fluids into the wound? If all four effects are important which one is dominant?

Some of these questions, undoubtedly could be answered if it were possible to reproduce in animals the types of wound infections which are encountered in man so that controls might be employed. Certain experimental procedures have been utilized to investigate a few phases of the problem and the results probably constitute the most reliable data now available but it must be recognized that no one experimental system can answer the question of say the treatment of choice for a carbuncle on the back of a man's neck.

Confusion in clinical research on sulfonamides has been further compounded because of the rapid succession of new drugs which have been introduced the diversity of physical forms, vehicles, doses, and time schedules in which they have been employed and fundamentally to a failure to recognize the limitations of local sulfonamide therapy. Dr. Frank Meleney has recently published a preliminary report of a comprehensive controlled investigation of the value of systemic and local sulfonamides in the prevention of local wound infection in accidental wounds and burns, a project of the Subcommittee on Surgical Infections of the National Research Council. After Pearl Harbor there was little doubt in the minds of some of us associated in this study but that prophylactic sulfonamides would both reduce the mortality from infection in war wounds, and also permit uncomplicated healing of most penetrating wounds subjected to debridement and closure within a reasonable time after injury. Consequently it was a distinct surprise finally to discover that the frequency of local wound infections was actually somewhat higher in wounds treated locally and systemically by sulfonamides than in control wounds receiving no drug at all by either route. The frequency and severity of local infections were largely influenced by the balance of the factors which relate to wound healing *per se* but not at all by our efforts to control the growth of bacteria in the wounds by implantation of sulfonamides before closure. We shall have occasion to return to this study later on but at this time I wish

only to use this passing reference to one specific study in order to complete the introduction of two cardinal facts about clinical research on local chemotherapy.

1 Every agent should first be evaluated in terms of the specific objective which it is supposed to achieve rather than in general terms, e.g. Does it provide bacteriostasis against a certain organism in wounds? or Does it delay healing of simple clean wounds? Not Does it produce unexpectedly rapid healing of infected wounds in general? After all, healing is the integrated outcome of many phenomena, particularly if the wound is infected and the rôle of the agent under test must be assessed in specific terms.

2 It is essential to use controls particularly those which will evaluate the vehicle in which the supposedly active agent is being employed and which will determine the significance of the physical conditions to which the wound is being subjected i.e. dryness, moisture, osmotic effect, pH, foreign body reaction etc.

It may be exceedingly difficult and at times even impractical to meet these two criteria of sound research, but unless this is possible the present deplorable state of confusion must inevitably continue and the improvement in our methods will be regrettably delayed.

For several years this department has been interested in certain fundamental considerations relating to the healing of infected wounds. One of the most thought-provoking chapters in this series of studies was written by Dr. David P. Anderson who compared the healing curves of infected wounds, calculated according to the standard formula of DuNouy and based on daily changes in area and volume. The effect of various antiseptic dressings was measured by daily counts of bacteria in the wounds. Through this carefully controlled procedure Anderson was able to conclude that drained infected wounds healed at the same rate as clean wounds provided invasive infection and slough were not present. Antiseptics such as azo-chloramide frequently induced sharp reductions in bacterial counts but failed in so doing to accelerate wound repair to any appreciable extent. It was finally

cluded "In the management of infected wounds, less attention should be given to the selection of a potent local antiseptic agent. It is of more importance to consider the problem of increasing local tissue immunity which may be influenced by factors of a general nature remote from the site of the wound and aiding the sequestration of necrotic tissues rich in bacteria by mechanical or chemical débridement and adequate surgical drainage.

Although Anderson included sulfanilamide solution among his series of antiseptic agents he did not employ sulfonamide powders or ointments. We may now re-examine some of the recorded experience with the topical use of sulfonamides in infected wounds in order to determine whether these agents impose a new and more favorable set of conditions for topical wound therapy.

TYPES OF CONTAMINATION

In order to systematize this discussion we should consider the local use of sulfonamides in the following types of contaminated or infected wounds:

1 Fresh contaminated accidental wounds, just after injury

2 Contaminated accidental wounds many hours old but not treated surgically

3 Contaminated wounds which have been débrided or trimmed and left unsutured possibly in anticipation of secondary suture

4 Wounds similar to the preceding category but closed primarily with or without tension

5 Wounds displaying invasive cellulitis without slough.

6 Wounds containing slough and deep cellulitis.

7 Granulating wounds displaying only superficial surface infection

Definitions A contaminated wound is one in which the implanted bacteria have not yet commenced to multiply and produce toxins. An infected wound may be defined as one in which death of tissue or increased morbidity occurs as a result of the activity of bacteria in the region of the wound. These definitions are deliberately phrased so as to provide for an intermediate category of saprophytic lesions, in which bacteria are proliferating in surface

fluids or in tissues already deprived of their architectural integrity and blood supply but without the bacteria actually aggravating tissue loss or contributing to increased morbidity. Obviously the border lines between these three types of wounds are quite hazy and differentiation may at times be impossible.

1 Fresh contaminated wounds just after injury The objectives in the first aid management of these wounds are to prevent additional contamination particularly by air borne and droplet borne pathogens from respiratory tracts of human carriers to provide immobilization during transport of the patient and to prevent or at least delay the proliferation of bacteria already present in the wound. Here the conditions are if ever suited to effective utilization of local sulfonamides.

It is theoretically possible to prevent or modify the growth activity of most of the pathogenic species particularly since the numbers are comparatively small and the liberation of specific inhibitors from damaged tissue will not yet have commenced. Furthermore there is no well established barrier between the bacteria and the drug which as shown by Hawking (7) will tend rapidly to diffuse throughout the surface of the wound. Questions of possible interference with wound healing do not intrude because the period concerned usually spans only a few hours during transportation of the casualty to a surgical theater. The value of applying sulfonamides to wounds immediately after contamination has been amply supported by a number of experimental studies in animals including those of Nitti, Reed and Orr, Caldwell and Cox and Hawking (7).

This is the altogether rational background for the widespread utilization of immediate prophylactic administration of sulfonamides to wounded soldiers. In our Army and Navy the current practice calls for the administration of 4.0 grams of sulfadiazine by mouth and the application to the wound itself of 5.0 grams of sulfanilamide both to be repeated after an interval of time at the discretion of a medical officer. The recommendation of sulfanilamide as the drug of choice for local use by the Committee on Chemotherapeutics and

Other Agents, was based upon the higher solubility and diffusibility of this drug and its freedom from deleterious effect upon wound repair. It was believed that these considerations more than outweighed the demonstrably greater antibacterial effectiveness of the less soluble drugs such as sulfathiazole and sulfadiazine, particularly during the first 24 hours after injury. Even after many months of war fare it is difficult to assess the true value of prophylactic sulfonamides used in this way. Some reports suggest that patients treated with sulfonamides actually reach base hospitals in much better shape than could have been expected under former conditions but there are many opinions to dispute this contention and other factors in first aid treatment, such as plasma, may account for the improvement. In our civilian experience most patients reach the operating room within 3 hours of injury so that this question can be answered only by studies on war casualties, and controlled observations have not yet been published. The most that can honestly be said for prophylactic sulfonamide in wounded soldiers is that the practice is entirely rational, and that no evidence has been brought forward to contraindicate its use. Therefore in the opinion of the writer there is every reason to continue the practice. The efforts of various workers to develop improved forms of the drug and vehicles for its slow liberation should be given every encouragement. An interesting example of progress along this line is the work of Hare and Clark, of Toronto, who recommend methyl cellulose as a solvent for sulfonamides when applied to contaminated open wounds. A combination of 30 per cent sulfathiazole and 70 per cent methyl cellulose implanted in the powdered state into open wounds will continue to liberate the drug over a period of several days, but of course must be completely removed from the wound before closure is carried out.

2. *Accidental wounds more than twelve hours old but as yet untreated.* Here again all considerations of reason would support the wisdom of introducing into the wound any drug which might check the already active proliferation of contaminating bacteria. The use of the drug may help to prevent invasion of tissue

planes on the verge of suffering irreversible damage through infection. The production of certain proteolytic or aggressive toxins may be suppressed through the bacteriostatic action of the sulfonamide. Obviously the drug effect will be less pronounced on wounds of this type than on fresh wounds, nevertheless, one may still recommend that they be used. Almost certainly they will do no harm. If extensive contamination with anaerobes has occurred the usefulness of local sulfonamides is definitely open to question, particularly if putrid saprophytic infection has developed.

Wounds of the latter type are comparatively rare in civilian life but have been described by J. D. MacLennan as having been not infrequent among casualties in the Middle East. The predisposing factors are (1) the presence of a lacerated wound, (2) delay in surgical treatment, and (3) contamination with one or more types of clostridia—usually the proteolytic and pathogenic varieties.

In wounds in which contamination has proceeded to this degree, it seems most unlikely that the employment of local sulfonamide applications would exercise much influence on the healing of the wounds. The specific objectives should be to hasten the separation of slough by surgical or chemical methods and to prevent invasive infection by means of systemic chemotherapy and serum therapy and immobilization of the wounded part. Since sulfonamide inhibiting products of proteolytic degradation are present in abundance in such wounds the already limited action of sulfonamides against clostridia and other anaerobes would be quite ineffective even in preventing the development of putrid surface contamination of this type, if the other predisposing factors happen to exist.

3. *Contaminated wounds which have been debrided or trimmed and left unsutured (possibly in anticipation of secondary suture)* Because of the well founded prejudice against primary closure of battle wounds it is certain that most war wounds will ultimately fall into this category. After surgical treatment the dressing will consist usually of tamponade with vasoline-impregnated gauze or plain gauze, supported either by an immobilizing splint or plaster cast. The incidence of serious

invasive infection in wounds so treated is generally thought to be quite low. In the series of civilian wounds studied in the National Research Council project previously referred to (Meleney) the incidence of serious local infection in soft part wounds débrided and left open was only 1.8 per cent. Although the corresponding figure for compound fractures left open was 16.5 per cent, a difference partly attributable to the greater damage to tissue in the latter cases, the mortality from infection was only 0.34 per cent in the combined group. The experience of Trueta was to the effect that gas gangrene and lethal infection occurred in only a fraction of one per cent of major compound fractures treated by débridement and plaster encasement. Therefore the major question here is whether or not local sulfonamide will hasten the healing time of the wounds and shorten convalescence either through minimizing bacterial interference on wound repair or through permitting early secondary suture of certain of these wounds. If the wound is to be immobilized in dressing or plaster for a period of many days it is doubtful that the presence of any reasonable quantity of sulfonamide initially will provide an effect of sufficiently long duration to do more than delay bacterial proliferation. If the drug is reapplied every day or two the necessity for repeated dressing and exposure of the wound may well offset any possible advantage which the drug might offer. Here again it can only be said that experimental and clinical data are not yet available to provide conclusive evidence of the value of local sulfonamide therapy in open wounds which have been subjected to good surgical care. The most important therapeutic considerations after débridement appear to be (1) complete immobilization to permit establishment of barriers between traumatized and untraumatized tissues and (2) performance of secondary suture or skin-graft as soon as the danger of invasive infection has passed perhaps only after 4 or 5 days have elapsed.

4 *Contaminated wounds which have been débrided or trimmed and closed primarily with or without tension.* Because of the unanimity with which the practice of primary closure of wounds is condemned in military

circles, it may be agreed that this is not a military problem. However, it is undoubtedly a problem of major importance in civilian surgery. There has been an increasing tendency for surgeons to undertake primary closure of traumatic wounds. In most hospitals in the United States and one explanation of this trend is the widespread faith which exists in the effectiveness of locally applied sulfonamides in preventing infections in such wounds. That this faith is based more upon impression than fact is indicated by the recent report of Meleney. In the series of wounds studied under the program of the Subcommittee on Surgical Infections, the incidence of serious infections in soft part wounds closed without local sulfonamide (303 cases) was 5.3 per cent. When sulfonamides were used both locally and systemically (339 cases) the incidence of infections was 5.6 per cent. With compound fractures the corresponding figure for control cases was 7.1 per cent (in 99 cases) and for sulfonamide treated wounds 1.1 per cent (227 cases). There is little comfort in these figures for the advocate of topical sulfonamides in closed contaminated wounds. There was virtually no problem of mortality among these patients. When serious infections did develop among even control cases they were always treated with sulfonamides and in fact only 4 deaths from infection occurred among the first 1,500 cases studied including the burns. However, the incidence of complicated healing of the local wound was at least as high when sulfonamides were used as when they were not used. The types of local sulfonamide included sulfanilamide alone, equal parts of sulfanilamide and sulfadiazine and more recently sulfathiazole. In most cases the amount used was 0.1 gram per square inch of wound surface but smaller quantities were used in some instances. In analyzing this experience it is apparent that the types of wounds in which complicated wound repair would be expected such as large wounds, those showing maximal injury to tissue or maximal contamination and wounds closed under tension tend also to become infected wounds. The use of sulfonamides which at most produces a transient repressive action on bacterial growth does not in any way modify the likelihood of infection.

developing. Sulfonamides probably fail to influence the frequency of infections in closed wounds for two main reasons: (1) The conditions which make for delayed or complicated healing are the very ones in which sulfonamide action is least effective, due to presence of sulfonamide inhibitors from devitalized tissue and (2) the presence of any foreign body in a closed wound tends to complicate the process of wound repair—even though the foreign body is a bacteriostatic agent, the danger of infection may to some extent be increased by its presence.

The influence of topical sulfonamide powder on the healing time of closed experimental wounds has recently been studied in our laboratory by Dr. Harold Zintel. Wounds treated locally with sulfanilamide showed development of tensile strength at exactly the same rate as control wounds. However when the less soluble sulfonamides were used including sulfadiazine and sulfathiazole in both microcrystalline and macrocrystalline forms, there was a marked retardation in healing time, particularly striking at the 8th day. It is very likely that such a delay in completion of the reparative process will more than outweigh in its consequences the possible beneficial action of local bacteriostasis. It should be emphasized that the interference on wound repair by sulfonamides may be minimized by the use of very small quantities of the drug, but one may now question the wisdom of using them at all in civilian wounds which can be debrided early and closed.

We have had forcefully emphasized to us the cardinal importance of the basic physiologic factors in treatment of wounds, namely removal of all irreversibly damaged tissue and foreign bodies, avoidance of tension in closure and thorough immobilization of the wound during the reparative stage. These considerations remain of far greater importance in the prevention of infection in closed wounds than the employment of any topical antibacterial agents thus far available. If some agent could be found which would completely destroy all bacteria in the area of the wound then the incidence of infection in closed wounds might actually be lowered, but such an agent is not yet available.

5 *Wounds displaying invasive cellulitis without slough.* In these wounds the bacteria have become successfully adapted to the environment of the wound and have not only multiplied but have commenced to invade the tissues adjacent to the wound either by direct bacterial invasion or liberation of toxins they have commenced to produce systemic manifestations of their presence in the wound. At the same time, the bacterial injury to the architecture of the wound surfaces has not yet become irreversible. Can an infection of this type be modified by the topical application of an antibacterial agent such as a sulfonamide? It seems hardly likely unless the infected area is first excised. The most important component of such an infection is the advancing margin of the process—well below the surface of the wound. Whatever the effect of the sulfonamides might be on the bacteria in the superficial wound exudate, they do not possess the capacity to penetrate deeply below the wound surface in high local concentration and halt the activity of bacteria below the level of the most superficial capillary layer. Hawking showed that the concentration of a sulfonamide from a wound depot was no higher at a depth of 2 millimeters below the surface than in the body tissues remote from the site of the wound (8). Therefore the systemic administration of sulfonamides is most certainly called for in the invasive infections of this type but there is little if any rational basis for the topical use of the drugs. Furthermore there is as yet no adequately controlled clinical experience which may be cited in support of the employment of sulfonamides in this category of infected wounds. Immobilization, elevation, induced hyperemia, free drainage and systemic chemotherapy must provide the basic therapeutic defense against threatened rapidly spreading invasive infections from wounds of any type. The remarkably low incidence of fatal invasive infections among our soldiers must be attributed largely to the thoroughness with which these measures have been applied.

6 *Wounds containing slough and deep invasive infection.* Serious infections in this category may develop in inadequately debrided accidental wounds or in third degree

mons, but the most common prototype is the carbuncle with the *Staphylococcus aureus* the usual causative organism. Such a lesion commences as a cellulitis which spreads until effective inflammatory localization is brought about by immunity or chemotherapy. A major consequence of the cellulitis is the occlusion of the vessels in the infected area by compression or thrombosis so that death of skin and subcutaneous tissue occurs followed by formation of slough and finally fluid pus. The surgeon may release tension and perhaps remove all or part of the dead tissue. The spread of the lesion may perhaps be reduced by administration of chemotherapeutic agents systemically. However there does not yet seem to be any evidence whatever that the local use of sulfonamide drugs either before or after surgical drainage will exercise much influence on the course of the lesion and in view of the pathological characteristics of these wounds none should be looked for.¹ Dressings which encourage drainage, separation of slough, and 'exsiccation' are undoubtedly of value; the application of heat will raise local metabolism and thereby hasten the process of resolution (though the amount of necrosis may be increased through widening the differential between oxygen supply and demand) however these measures are not directed specifically against the bacteria themselves. It would be most unfortunate if a misdirected faith in chemotherapeutic agents were to lead to the abandonment of those measures of treatment which are rooted in basic understanding of the inflammatory process.

7 *Granulating wounds displaying only superficial surface infection*. After slough has separated and invasive infection is under control the main objective in therapy is to obtain complete healing and epithelization as rapidly as possible. Such healing occurs both through contracture and through growth of epithelium from the periphery but may be greatly accelerated by application of skin grafts. Therefore the yardstick for measuring the usefulness of local sulfonamide in

wounds at this stage is whether or not the net effect is to facilitate growth of epithelium. If it is true that the presence of some types of bacteria, particularly Group A hemolytic streptococci interferes both with epithelization and with successful application of skin grafts then, from a purely bacteriologic viewpoint, the local use of sulfonamides against these susceptible varieties of organisms would seem to be entirely rational. According to Colebrook and Francis the use of sulfonamides locally in granulating burns infected with streptococci has been eminently successful in causing disappearance of susceptible strains and the same results could probably be obtained on other types of open granulating wounds. At the same time one must guard against using the drug in a form which is ill adapted to encouragement of wound healing. For example the application of a sulfonamide preparation which tends to dry out cake and mechanically injure the new growth of epithelium or one which causes the formation of edematous exuberant granulation might gain on the bacterial front but lose the campaign in other sectors. Also as has been emphasized by Gurd Ackman Gerne and Pritchard one must be assured that the sulfonamide is available in an effective concentration in the aqueous phase and yet not absorbed so rapidly by the body as to preclude its use on large areas through danger of excessive absorption. The development of the ideal vehicle for application of sulfonamide the choice of the particular drug to be used and the factors of time and concentration required for optimum results provide an important subject for further intensive laboratory and clinical research. However there is great need for control of this investigation at every turn so that when the evidence is finally accumulated there will be general acceptance of the conclusions. Furthermore it would be desirable to obtain further evidence that the presence of a purely surface contamination of a granulating wound with pathogenic bacteria is a significant factor in delaying wound repair. Anderson's data failed to indicate that such was the case.

I do not believe that we would be greatly handicapped in the treatment of open granulating wounds if sulfonamides were not avail-

¹Penicillin appears to be superior to sulfonamides as an antibacterial agent for topical use in infected wounds. This drug is not inhibited by products of tissue breakdown. Impressive results of local penicillin therapy as an adjunct to surgery in controlled study of hand infections have been reported by Flory and Williams, *Lancet*, 1944, 23.

able. Other methods of preparation of the wound, including zinc peroxide Dakin's solution, and azochloranamide, have all been used with success in our hands and it seems possible that with each of these agents the antibacterial effect is of less importance than the effect of the treatment on the architecture of the granulating bed.

Local sulfonamide therapy of burns Because of the increasing importance of burns in both military and civilian life the war years have been accompanied by an intensive re-examination of the whole problem of burn management. Certain fundamental advances have come through the growing recognition of the fact that burns are extensive open wounds and should be treated as such namely by protective dressings and immobilization. The use of coagulating chemicals which add further injury to the burned tissue block drainage render infection more serious when it occurs, and perhaps aggravate toxemia, is rapidly falling into disrepute. This is partly because the availability of large quantities of blood plasma has now made it possible to deal effectively with the major factor of plasma loss, in which tanning methods were thought to be especially helpful. Reports from medical officers in the Middle East and elsewhere are almost unanimous in condemning the practice of tanning burns in forward areas, where treatment must be initiated before the casualty is transported.

Early in 1942 Allen and Koch reported on a three year experience with the use of careful cleansing and nonadherent splinted compression dressings and courageously declared that the tannic acid treatment was outmoded. The basic principles advanced by these authors have now received wide support. One question which has not been answered with finality is whether sulfonamide should be incorporated in the compression dressing. The series of cases reported by Gurd Ackman Gerrie and Pritchard of Montreal is a testimony to what can be accomplished through sound planning and teamwork in burn management and the use of heavily padded compression dressings. The treatment of 100 major burns of over 20 per cent of body surface with only 6 deaths (all over 35 per cent) demonstrates what can

be expected from such a regimen. However in view of the results obtained by Allen and Koch the question may properly be raised as to whether the results of the Montreal group might have been equally good had the emulsion which they used contained no sulfonamide. We may all agree that the provision of a low systemic blood level of sulfonamide during the first few days after a burn probably helps to reduce the likelihood of invasive streptococcal or staphylococcal infection. However so many factors combine together to reduce the effectiveness of sulfonamides in the presence of necrotic burned tissue as to rule out an *a priori* acceptance of the value of the local drug *per se*. In the series of cases from the co-operative project reported by McLeney the use of compression dressings appeared to have a more important bearing on the reduction of infection than did the use of sulfonamides either generally or locally. Of the 347 cases included in McLeney's report only 2 patients died as a direct consequence of infection and each of these received sulfadiazine both locally and systemically. The value of local sulfonamides in burn therapy can be established beyond question only by a carefully controlled project such as that which is now being carried out in Montreal, and we all await the outcome with keen interest.

SUMMARY

In directing his efforts to shorten the healing time of various types of contaminated and infected wounds, the surgeon must be realistic in selecting his tools to suit the principal objectives in each individual case. The maintenance of bacteriostatic conditions on the surface of the wound is the only objective which can reasonably justify the topical use of sulfonamides. This objective is limited in its importance in most established infections, and limited in its attainment through the use of sulfonamides because of the inhibitory effect of products of tissue breakdown on sulfonamide action. Priority should always be assigned to measures which achieve optimal conditions for wound healing and direct antibacterial measures should usually take secondary position in local treatment. Systemic chemotherapy supplementing a form of topi-

al therapy which is adapted to the local pathological condition will generally provide the best approach both to prevention and treatment. Local sulfonamide applications are probably useful in the first aid management of contaminated wounds between injury and definitive surgical treatment, and in preparing open granulating wounds for application of skin grafts, but are of little demonstrable value in the treatment of wound suppuration or invasive infection.

Definition of specific objectives and utilization of controls are essential features of any research but are particularly indispensable to the evaluation of chemotherapeutic agents in local wound therapy.

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THYROID FUNCTION AS A FACTOR IN GALL BLADDER DISEASE AND FORMATION OF GALL STONES

Clinical and Experimental Study

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A GREAT quantity of work has been carried out in recent years in an effort to find the cause of chronic gall bladder disease much still remains obscure. Most authors agree that the chronically infected gall bladder with or without stones as we commonly see it at the operating table represents one of the final chapters in a long standing disease of the organ.

The pathogenesis of gall bladder disease both cholecystitis and cholelithiasis, was at first thought to be due entirely to infection. We have learned however that other factors such as biliary stasis, the presence of pancreatic enzymes, hepatic insufficiency and changes in the bile itself must be considered. Most experimental work to date has attacked the problem as a purely local disease of the gall bladder and biliary passages. This study was undertaken to attack the problem as one of both a local and systemic nature associated with a disease which affects body function generally namely hypothyroidism.

Our modern knowledge of cholecystitis began in 1890 with the work of Gilbert who advanced the infectious theory of the disease. Then followed the studies of Gilbert and Fournier of Wilkie and Doubilet of Phemister Day and Hastings, and of many others most of whom studied the activity and reaction of the gall bladder in the presence of induced infection. The colloidal chemical theory of gall stone formation was introduced by Aschoff in 1891. His work was followed and elaborated later by Aschoff and Bacmeister, Shade Exner and Heyrowsky and many others. Mentzer Illingworth, Boyd and others believe gall-stone formation is the result of difficulty in absorption of cholesterol by the

gall-bladder wall. Graham and others advance the theory of supersaturation and precipitation of cholesterol occurring as the result of excretion of cholesterol by the gall-bladder wall. This process they believe is accentuated by infection.

With the accumulation of data more and more evidence points to stasis as an important factor in this disease. Phemister Aronsohn and Pepinsky noted a change in the type of stone found depending upon the degree of stasis present. Andrews Dostal and Hrdina reported that stasis is usually accompanied by infection which in turn results in the absorption of bile salts by the gall-bladder wall.

A few authors have noticed pigment stones associated with stasis. Aronson produced pigment stones in two dogs after mechanically inducing partial common duct obstruction. Cole Novak, and Hughes reported similar stones in two of their animals after partial obstruction of the cystic duct was produced. These animals in addition showed chronic inflammatory changes in the gall-bladder walls. Bigard and Baker obstructed the common ducts of goats just distal to the entrance of the pancreatic ducts. This allowed pancreatic enzymes to enter the gall bladder. In three of the goats in which stasis had been prolonged several small pigment stones were found in addition to evidences of chronic infection of the gall bladder walls.

Most of the experimental work of the aforementioned authors and of many others has attacked the problem as an entirely local disease. Is there a deficiency disease which could affect gall bladder function? Certainly infection stasis and chemical changes occur but is there some internal secretion the lack of which would cause improper function of the gall bladder and thereby lower the resistance of the organ to infection and the associated

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anges we commonly find? With this in mind and because hypothyroidism and cholelithiasis have many common relationships the effect of thyroid insufficiency on biliary function was selected for study. Hertough in 1900 pointed out a possible relationship between these two diseases. Butler and later Loranger again pointed out an existing relationship between these two diseases and denied the fact that no experimental work had been done on the problem. Fortune, Brandon, Davis, Vis, Barksdale, and many others have shown that mild degrees of hypothyroidism are frequently associated with the gastrointestinal symptoms commonly seen in cholelithiasis. J. W. Hinton reviewed 43 cases of hypothyroidism which presented the typical symptoms of peptic ulcer. Riegel, Ravdin, and Morrison noted that thyroid disorders are frequently associated with gall bladder disease.

It is of more than passing interest that all gall stones contain cholesterol. A high blood cholesterol level is found in both gall bladder disease and hypothyroidism. Epstein and Lande, Gardner and Gainsborough, Hurxthal and others have noted an inverse relationship between thyroid function and the blood cholesterol level and many believe that the blood cholesterol level is a more accurate index of thyroid function than the basal metabolic rate.

Both hypothyroidism and cholecystitis are much more common in females and both diseases are associated with obesity. Almost any busy clinician can look back and remember patients with gall bladder disease who presented the typical picture of hypothyroidism. This is especially true of women whose thyroid is apt to become depleted during pregnancy and with the onset of the menopause a time when gall stones often occur.

Basal metabolic rates were taken on 50 normal adults in this clinic. Two per cent of the patients had rates between +15 and +10, +10 and 0, 54 per cent of the patients had rates between 0 and -10, 4 per cent had rates between -10 and -15, and 4 per cent had rates below -15. Fifty consecutive cases of

chronic cholecystitis were subjected to basal metabolic studies. Twenty four per cent of these patients had rates between +10 and 0, 40 per cent had rates between 0 and -10, 22 per cent had rates between -10 and -15, and 14 per cent of the patients had rates below -15.

Blood cholesterol studies were done on the aforementioned series of 50 cases of chronic cholecystitis. These studies showed 33.7 per cent of the cases within normal limits (184 to 190 mgm. per cent) and 47.6 per cent showed a high blood cholesterol level (190 to 250 mgm. per cent). Cholesterol determinations were made according to the methods of Myers and Wardell and all specimens were taken with patients fasting. Of 161 cases of chronic cholecystitis entering the hospital, 87.6 per cent were obese, 6.6 per cent slightly overweight, and 5.8 per cent normal or below.

We believe that these figures show a definite trend toward hypothyroidism in these patients. Bockus and Willard in a similar study found only 11.1 per cent of their patients had low basal rates, but 51 per cent of their patients showed a blood cholesterol level of over 200 milligrams per cent. They were also of the opinion that their patients showed evidences of thyroid dysfunction. Higgins has shown that marked symptoms of hypothyroidism are often seen with but moderate changes in the basal metabolic rate. In view of this and also of the recent studies of Hinton, Musser, Seward and others, the significance of the foregoing figures may be greater than one would expect.

EXPERIMENTAL STUDIES

The experimental approach to the problem was divided into a number of parts in order to determine (a) the effect of a prolonged hypercholesterolemia as induced by thyroidectomy on the chemistry of the gall bladder bile, (b) similarly to study the effect of thyroidectomy and induced hypothyroidism on biliary output and hepatic bile chemistry, (c) under similar conditions the effect of a prolonged hypercholesterolemia on the gall bladder and (d) gall bladder function in these animals by means of cholecystograms.

By this method the total daily bile output was collected measured and cultured. About 10 cubic centimeters of each daily sample was taken for study and the remainder was fed back again to the animals through a stomach tube.

Each normal and experimental animal was studied for a period of 10 days and the average daily bile output in cubic centimeters, bile salt and cholesterol content, bile salt-cholesterol ratio, daily bile salt and cholesterol output and blood cholesterol levels were determined. The results are shown in Table III. Three of the experimental animals were discarded. One of the animals died of bile peritonitis and the other 2 showed clinical evidences of biliary infection and had positive bile cultures.

The blood cholesterol levels in the experimental animals remained high throughout the course of the experiments; however in spite of this the bile cholesterol values remained within normal limits. The total daily output of cholesterol by comparison showed an insignificant change.

There was a notable difference in the total daily output of bile and also in the bile salt content of bile from thyroidectomized animals. The bile salt content was not inversely proportional to the daily output of bile. The bile salt-cholesterol ratio in the experimental dogs was 73.8 while in the normal dogs it was 151.4. This ratio of 73.8 is still far above the critical level for cholesterol precipitation (13) as described by Andrews and associates. Whether the ratio and bile salt content would fall still farther if the animals were allowed to remain in a hypothyroid state for a longer period of time (1 or 2 years) is a matter for further study. Four grains of thyroid extract were given daily to 3 of these animals, and after 6 to 8 days the total bile output and bile salt content rose to comparatively normal levels. This, however, was not considered significant in view of the small number of animals studied. Autopsies on all animals revealed normal biliary structures, liver and kidneys.

C. Gall-bladder wall analysis. The gall bladder walls were studied both microscopically and chemically to determine whether a prolonged hypercholesterolemia associated

with the hypothyroid state would result in deposit of cholesterol within the gall-bladder wall. We were interested in finding out whether a condition simulating cholesterosis of the gall bladder could be produced experimentally.

Total thyroidectomy was performed on 10 normal dogs. After a period of hypercholesterolemia ranging from 2 to 5 months the gall bladders of these animals were removed. The gall bladders of 7 normal animals were also removed and these were used as controls. Blood cholesterol levels of the normal animals varied from 127 milligrams per cent to 149 milligrams per cent; those of the experimental animals varied from 176 milligrams per cent to 230 milligrams per cent.

Small biopsy specimens were removed from each gall bladder and the remaining portions were washed with saline and dried to constant weight. The specimens were frozen and frozen sections were made. The sections were then stained according to the Schultz technique for demonstrating cholesterol. With this method cholesterol is stained a greenish hue which lasts about 1 hour. When these sections were examined microscopically small concentrations of green pigment were noticed beneath the mucosa and submucosa. There appeared to be more of this deposit in the gall-bladder walls of the thyroidectomized dogs than in those of the normal controls.

The gall bladders were carefully washed with saline and dried to constant weight. The cholesterol was then extracted from them and a quantitative determination of the amount present was made. Tables IV and V show the values obtained for the normal and experimental animals. The average content of cholesterol in each gall bladder wall per gram of dry weight specimen was 0.0132 milligram for the control group and 0.0101 milligram for the experimental group.

The smaller value for the experimental group cannot be taken to indicate that hypercholesterolemia causes a reduction in the cholesterol content of the gall bladder wall since there is a normal variation. The results obtained from quantitative analysis of the gall bladder walls must be considered more significant than the microscopic studies since

SMENDINGER THYROID FUNCTION AND GALL-BLADDER DISEASE

IFHS IV AND V — QUANTITATIVE CHEMICAL DETERMINATION OF CHOLESTEROL CONTENT IN GALL-BLADDER WALLS OF NORMAL AND HYPOTHYROID DOGS

Table IV — Normal Dogs

Dog number	Blood cholesterol	Dry weight specimen—gm	Cholesterol content—mg/gm	Cholesterol content per gram dry specimen—mg/gm	Duration of hypercholesterolemia
20-6	34		4.44		
39	27	3.5	263	156	
39-140	43	23	4.83	0074	
39-28	15	267	3.34	100	
42-79	41	10	05	3	
42-60	10	3.4	3.500	0034	
42-	37	415	3.07	01.3	
				000	

Table V — Hypothyroid Dogs

Dog number	Blood cholesterol	Dry weight specimen—gm	Cholesterol content—mg/gm	Cholesterol content per gram dry specimen—mg/gm	Duration of hypercholesterolemia
37-130	3	135			
37-77	20	3.4	3.0	3	3 months
39-131	07.5		4.0	20	4 months
39-162	76		9.6	20	5 months
39-5	08	70	8.85	4	7 months
39-1	03	23	3.4	0000.5	3 months 6 days
39-5	205	04	040	11	4 months 20 days
39-26	79.5	21	3.415	3	4 months 5 days
39-260	30	256	4	29	4 months
39-26	36	210	6	00	4 months
				0053	5 months
					5 months

the latter method is subjective. The values as demonstrated show neither an absolute nor a relative significant increase in cholesterol content in the gall bladder walls.

D. Studies on gall-bladder function. The most interesting and most significant findings in the entire study were noted while we were determining gall bladder function in these animals. When thyroidectomized animals were operated upon it was noticed that their gall bladders were almost always greatly distended. The bile contained in these gall bladders was found to be thick and viscid and contained a large amount of thick brown precipitate. On transillumination of this bile two definite layers appeared as shown in Figure 1: an upper layer of clear yellow bile and a heavier layer of black viscid material. In Figure 2 the bile alone is transilluminated. The two definite layers are easily distinguished. The thick sediment which contains numerous particles of pigment is illustrated also in Figure 3.

The gall bladders of 5 of the animals contained numerous small black friable concretions in addition to a large amount of viscid material. Figure 4 shows the concretions found in 4 of the dogs; the 5th was inadvertently not photographed. The concretions were analyzed by Dr. R. F. Hanzal of the department of biochemistry and were found to be composed of a trace of calcium and cholesterol but were for the most part composed of pigment and polymerized pigment soaps.

Concretions and precipitates such as the above have been previously noted after a prolonged period of biliary stasis. Aronson, Bischoff and Baker, and Cole, Novak and Hughes reported similar stones after mechanically induced experimental biliary obstruction of a partial type. In our experimental animals the gall bladders and biliary systems had been disturbed in no direct way. Thyroidectomy had been performed from 2 to 5 months previously and the concretions and

TABLE VI—RECORD OF GALL-BLADDER FUNCTION IN THYROIDECTOMIZED DOGS

Dog number	Total thyroidectomy	Blood cholesterol	Duration of elevation of blood cholesterol	Cholecystograms 4-12-40	Repeat cholecystograms 2-20-40	Thyroid extract or 4 started	Blood cholesterol 5-10-40	Cholecystograms given after thyroid administration	Thyroid extract stopped	Blood cholest. 47 days later	Total days thyroid given
Group I											
39-37	1-12-39	18	3 mos. 20 days	P hr	Failed	2-4-40	17.2	N Empty 2 hr	6-5-40	16.5	5
40-13	1-26-40	198	mos.	P 2 hr	Failed	2-12-40	20.2	N Prolonged 6 hr	6-5-40	20.3	1
40-	1-12-40	164	3 mos. 20 days	P hr	Failed	2-12-40	22	N Empty 3 hr	6-5-40	21	
40-1	8-9-40	143	mos.	P 2 hr	P 2 hr	2-2-40	27	SL Prod 2 hr	6-5-40	29	13
40-15	1-10-40	97	3 mos. 19 days	Failed	Failed	2-11-40	15	SL Prod 2 hr	6-7-40		17
Group II											
40-12	1-10-40	88	mos. 18 days	Failed	Failed	Control	197	Failed	Control	183	—
39-44	8-5-39	10	mos. 18 days	Failed	Failed	Control	13	Failed	Control	15.6	6
40-4	8-9-40	13	3 mos.	P hr	Failed	Control	13	Failed	Control	14.2	—
40-23	1-27-40	13	3 days	P hr	N 3 hr	Control	5	Prod 72 hr	Control	10.7	—
Group III (Control)											
Block	Normal	15	Normal		N hr	Control	—	Control normal emptying 3 hr	Control	15.9	—
Block	Normal	29	Normal		N hr	Control	—	Control normal emptying 3 hr	Control	1	—
Block	Normal	8	Normal		N hr	Control	—	Control normal emptying 3 hr	Control	14.7	—
Block	Normal	17	Normal		N hr	Control	—	Control normal emptying 3 hr	Control	17	—
Block	Normal		Normal		N 3 hr	Control	—	Control normal emptying 4 hr	Control	14.3	—

P—Gall bladder failed to contract.

F—Gall bladder emptying time prolonged.

N—Normal emptying time.

previously mentioned precipitates were noted when the abdomens of these were first opened in the process of study connected with biliary chemistry. Similar precipitates and stones were not found in the control animals. In view of the large amount of precipitate found in almost every one of our experimental animals which had been thyroidectomized for a period of 2 months or more we believe the factor of biliary stasis deserved further investigation.

Cholecystograms with careful emptying time studies were made in an effort to determine the power of the gall bladder to concentrate the dye and also the degree of stasis present. The average emptying time for normal animals was compared to that of the experimental animals receiving the same dose of dye. Fifteen normal dogs were used in the

study. Ten normal dogs were thyroidectomized while the remaining 5 dogs were used as controls. All animals were placed on the same routine kennel ration. Table VI shows graphically the progression and results of the study. One of the dogs died after thyroidectomy and is not shown in the table.

In all 9 of the experimental animals a hypercholesterolemia developed which varied from 187 to 255 milligrams per cent for the experimental animals as compared to a variation of from 135 to 142 milligrams per cent for the controls. Hypothyroid dogs were allowed to progress for periods varying from 18 days to 9 months and 18 days before further studies were attempted.

Cholecystograms were made in the following manner. Intravenous tetralodophenolphthalein (Mallinckrodt) 50 milligrams per



Fig. 1

Fig. 2.

Fig. 1. Gall bladder transilluminated to show heavy precipitate.

Fig. 2. Gall-bladder bile showing heavy sediment.

kilogram of body weight was mixed with 250 cubic centimeters of normal sterile saline and given to each animal at 6:00 p. m. on the evening prior to x ray studies. The animal was then kept fasting and the first roentgenogram was taken at 9:00 the following morning. The animals were then each given 1 pint of heavy cream and a second roentgenogram was taken one half hour after the first. Succeeding x ray pictures were taken at intervals of 1½, 3, 6, 12, 24, 48, and 72 hours except in unusual cases when they were taken more frequently. All plates were interpreted by Dr. Thomas Knickerbocker of University Hospitals x ray department who rendered invaluable assistance during this study.

A number of stock animals were studied and in each an excellent visualization of the

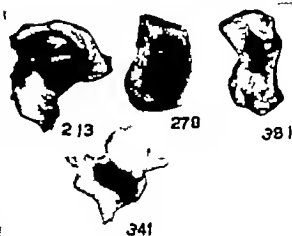


Fig. 3

Fig. 3. Several gall bladders which have been removed from hypothyroid dogs. These specimens show pigment precipitate.

gall bladder was obtained. In each of the normal dogs the shadow had decreased markedly in size and density 1½ hours after feeding. Within 3 to 5 hours after feeding the gall bladder shadow had entirely disappeared or remained only faintly visible. Results in 5 normal dogs studied are shown in Table VI.

By means of the same technique 9 thyroidectomized dogs were studied. In 3 of the animals no shadow was obtained. In the remaining 5 animals a fairly good shadow was obtained. Two of these animals showed an emptying time of 8 hours, 3 animals emptied in 12 hours and 1 animal in 24 hours. In each of these 6 animals the shadow after 3 to 5 hours was of the same size and intensity as it was prior to feeding and in succeeding plates decreased in intensity but not in size.



Fig. 4. Four gall bladders removed from hypothyroid dogs. The specimens show concretions and heavy precipitate.

Because of the marked difference in results obtained between the thyroidectomized and normal animals the entire roentgenographic study was repeated 2 weeks later the same animals and the same technique being used. In this study there was less evidence of good gall bladder function than in the first. In 7 experimental animals no gall bladder shadow was obtained. One animal showed a normal visualization and emptying time. Incidentally the latter animal had been thyroidectomized a much shorter period of time, approximately 2 months. Three of the animals failed to show a gall bladder shadow in both studies.

The animals shown in Table VI were divided into 3 groups. Groups I and II included the experimental animals and Group III was composed entirely of normal control animals. Five of the experimental animals in Group I were given thyroid extract 4 grains per day for 23 days. Animals in Group II were allowed to continue in a hypothyroid state. Blood cholesterol levels were carefully determined on all dogs. The animals in Group I showed a return to normal as shown by their blood cholesterol levels in approximately 23 days. The levels which had formerly been high (187 to 198 mgm. per cent) now varied between 117.5 and 150.5 milligrams per cent after administration of thyroid extract. In Group II animals not receiving thyroid extract cholesterol levels remained high varying between 182 and 258 milligrams per cent. Control animals were within normal limits.

Cholecystograms were again repeated to determine whether administration of thyroid extract in animals in Group I would have any effect on the x-ray results in that group as compared to the animals in Group II not receiving thyroid extract. The same technique as previously described was used.

A marked improvement in results was obtained. Every animal in Group I showed a good visualization of the gall bladder. Two animals showed a rapid disappearance of the gall bladder shadow after feeding while the remaining 3 showed only a slight prologation of the emptying time and were considered within the limits of normal.

In the group not receiving thyroid extract we were unable to obtain visualization of the

gall bladder in 3 of the animals. In the 4th animal excellent visualization was obtained but little change in intensity or size of the shadow was noted for 72 hours in spite of frequent feedings. Normal animals showed normal function and visualization. Thyroid extract was discontinued in the animals in Group I and a hypercholesterolemia developed varying between 161.7 and 212 milligrams per cent. Autopsies were carried out on all the animals. The gall bladders of the experimental dogs showed a large amount of precipitate but no signs of inflammation were noted. Microscopic sections of the liver, gall bladder, kidneys and great vessels were normal in appearance.

In reviewing the complete x-ray studies, it may be concluded that thyroid extract or a normal functioning thyroid gland is essential for normal gall bladder activity. The results in Group I were much improved after the administration of thyroid extract. Graham reported in 1925 that visualization of the gall bladder could almost always be expected if the organ was functioning normally. Many normal animals were examined in addition to those listed in the table and all gall bladders visualized normally. It appeared that the longer an animal progressed after thyroidectomy the poorer his gall-bladder function became. In one animal which had been thyroidectomized 4½ months previously and in another which had been thyroidectomized 9½ months previously the gall bladders failed to visualize on 3 successive occasions. The degree of hypercholesterolemia seemed to have little effect on visualization or emptying time in animals not receiving thyroid extract.

SUMMARY

We have attempted to determine clinically and experimentally whether a relationship between gall-bladder disease and hypothyroidism exists. Clinically the two diseases have aspects in common. Both are more common to middle aged females and are similarly associated with obesity. Digestive complaints such as nausea, epigastric pain, constipation etc. are frequently associated with both hypothyroidism and chronic cholecystitis. High blood cholesterol levels are seen in both dis-

eases. In this clinic 36 per cent of patients with chronic gall bladder disease showed basal metabolic rates of -10 or below and an additional 40 per cent showed a basal metabolic rate from 0 to -10 . Only 24 per cent showed a positive metabolic rate. This we believe is a definite trend toward hypothyroidism in these patients as compared to normal individuals.

A sustained elevation of the blood cholesterol occurred in thyroidectomized dogs appearing about 27 to 30 days following operation. A prolonged high blood cholesterol level (2 months or more) did not result in an increase in the cholesterol output in the hepatic bile. The hepatic bile salt content and total biliary output were somewhat low in these animals as compared to the normal. Gall bladder bile aspirated from the gall bladders of hypothyroid dogs showed a normal bile salt and cholesterol content in spite of the fact that an elevated blood cholesterol existed.

Gall bladder walls in hypothyroid dogs were studied microscopically and clinically for cholesterol deposit within them. No significant difference from the normal was found.

A most striking finding was noticed when the abdomens of the hypothyroid animals were first opened. The gall bladders of most all the hypothyroid animals were greatly distended and contained much thick brown precipitate. In 5 of the animals many concretions of various sizes were found. Chemically these concretions were composed of pigment, pigment soaps and traces of calcium and cholesterol. Such findings have been seen previously in dogs after mechanically induced stasis.

Several dogs were thyroidectomized and cholecystograms were made. As shown in Table VI the gall bladders of the experimental animals either failed to visualize or after visualization showed a prolonged emptying time as compared to the normal. In 5 of these thyroidectomized animals thyroid extract 4 grains per day was administered for 23 days after which cholecystograms were repeated and all animals receiving thyroid extract showed normal visualization and function of their gall bladders.

CONCLUSIONS

It may be concluded that the hypothyroid state does materially affect gall bladder function. The large quantity of debris and concretions found plus the x ray findings indicate that a marked degree of stasis takes place within the gall bladder. Apparently a high blood cholesterol as indicated by the hypothyroid state does not result in an increase in the cholesterol content of the hepatic bile nor does it result in a deposit of cholesterol within the gall bladder walls. Autopsy findings in all these animals revealed normal appearing gall bladder walls, liver, kidneys and great vessels.

Obviously infection plays a major part in the production of cholecystitis and cholelithiasis. However any constitutional disease which impairs gall bladder function would certainly render the organ more liable to bacterial invasion and would be a factor to consider in the ultimate production of chronic cholecystitis as we see it in its final stages. Heavy precipitate and pigment concretions as seen in these hypothyroid dogs might easily be held about which stones might form if infection were superimposed upon the condition already present. In view of this the hypothyroid state merits consideration as a contributing cause of cholecystitis and cholelithiasis and should be borne in mind when these patients are seen.

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PRISACRAL NEURECTOMY FOR INTRACTABLE VESICAL PAIN AND NEUROGENIC VESICAL DYSFUNCTION

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PRESACRAL neurectomy has been performed less and less frequently of late and at the present time is only rarely resorted to for the relief of intractable vesical pain and for the treatment of neurogenic vesical dysfunction. The reason or reasons for the present disinterest in this procedure may be either its apparent failure to meet the expectations originally held for it or else its gradual replacement by other procedures of proved and established merit. A review of all the cases in which presacral neurectomy has been performed at the Mayo Clinic for the relief of intractable vesical pain and neurogenic vesical dysfunction indicates that both of these factors have been responsible for the less frequent employment of this procedure. As 10 years or more have passed since the first presacral neurectomy was performed at the clinic it seemed like an appropriate time to review and to report the results of our experience with this procedure. Furthermore it would seem desirable to re-examine the rationale of this procedure particularly in view of the recent changes that have occurred in our concept of the theory of micturition and in our comprehension of the respective roles played in it by the sympathetic and parasympathetic divisions of the autonomic nervous system.

HISTORICAL REVIEW

The French school of neuroanatomists and neurosurgeons is responsible for the original investigative work and for much of our present knowledge of the rôle of the sympathetic nervous system in the innervation of the pelvic viscera.

Jaboulay in 1868 first suggested paralyzing the sacral sympathetic nerves for the relief of

certain types of pelvic neuralgia. For this purpose he advocated a retrorectal approach and advised resecting the coccyx and retracting the rectum forward until the sacral sympathetic chains and the sacral ganglia were exposed. Section of these nerves usually resulted in some relief of vesical pain and in a temporary retention of urine. Later others tried to obtain similar results by the injection of air or of artificial serum into the pelvic tissues but as the results were unsatisfactory the method soon was discarded.

Rochet and Latarjet in 1913 suggested the transperitoneal route for section of the nerves to the lower end of the ureter and to the bladder or the extirpation of the hypogastric ganglion. He employed this procedure for the relief of pain in tuberculous cystitis. However since he claimed that permanent urinary retention usually followed the operation it was gradually abandoned.

Lenche Hallopeau, Jianu and Cotte developed hypogastric periarterial sympathectomy. Cotte in 1925 reported his first cases in which presacral neurectomy (Cotte's operation) was performed and listed the indications for the operation as follows: (1) pelvic neuralgia (2) vaginismus (3) rebellious dysmenorrhea (4) uterine hypoplasia with scanty menstruation (5) metrorrhagia and leucorrhoea of ovarian origin and (6) sexual hyperexcitability, masturbation and so forth. Cotte later suggested its use for the relief of intractable vesical pain. Lien (1936) also performed presacral neurectomy for the relief of vesical pain but subsequently modified the operation to include resection of the lateral sacral and lower lumbar sympathetic ganglia.

All the aforementioned investigators performed the operation primarily for the relief of pain and it was not until Richer in 1939 treated atony of the bladder and of the colon by presacral neurectomy that this operation

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Many investigators have endeavored to relax the neck of the bladder and to alter the so called urethral resistance by sectioning the hypogastric nerves. Among these were McCrea and Macdonald (1934) who concluded that of these nerves did not cause relaxation of the internal sphincter of the bladder either in the cat (Barrington) or in man. Furthermore they were unable to obtain experimentally any evidence of a convincing nature of either an inhibitor or excitator action on the sphincter. Denny Brown and Robertson also denied the existence of any such effect. Van Duzen (1937) concluded from his researches on the rhesus monkey that section of the presacral nerve did not result in any relaxation of the internal sphincter and that stimulation of the nerve resulted only in a contraction of the trigone. It was not followed by either contraction of the internal sphincter or relaxation of the detrusor muscle. Langworthy Drew and Vest (16) in 1940 found that the urethral resistance of the cat was not appreciably affected by section of the abdominal sympathetic trunks and concluded that abnormalities of micturition due to injury of the nervous system are dependent primarily on difficulties of contraction of the detrusor muscle and only secondarily to changes in urethral resistance. The term sphincter disturbance is a misnomer.

All of the previous discussion has dealt with the possible rôle of the sympathetic system in the regulation of the tone of the internal sphincter or in the control of the so called urethral resistance. Little or no mention has been made of the sympathetic system as a pathway for the transmission of sensory stimuli from the bladder. Since presacral neurectomy originally was designed to relieve pain by the direct interruption of the principal sensory pathways it is not surprising that the results have been disappointing since relatively few of the sensory impulses are carried by the hypogastric nerves. Quinby (1931) in reporting a case in which interstitial cystitis was treated by presacral neurectomy, remarked "When one considers that the urinary bladder may send afferent impulses through three different nervous pathways it would seem doubtful that the removal of only one

and that a rather minor one could bring sufficient relief to be of significance. Learmonth (20) was of the same opinion and in 1931 said

I do not feel that vesical pain can be completely controlled by section of the presacral nerve. That some relief of vesical pain occurs after presacral neurectomy is apparently true particularly relief from the feeling of intolerable distention before micturition. Learmonth (20) in 1931, Foulds (1932), McConnell (1933) and Douglass (1934) reported evidence to support this point of view. According to Cheetham (1937) this relief of pain has been attributed to relaxation of the internal sphincter with relief of spasticity to the cutting of some sensory fibers in the hypogastric nerve and to the vasodilatation which may relieve pain occurring as the result of ischemia of the bladder wall. Furthermore the relief of pain when it was obtained usually was only partial. Nesbit also has reported relief of pain and vesical spasm by presacral neurectomy in cases of intractable infection of the bladder. He said that the operation should be performed only in those cases in which pain is clearly demonstrated to result from spasm of the vesical outlet.

Learmonth (19) was well aware that many problems still remained unsolved. In fact his article was prefaced by the following statement. The surgeon must be on his guard against over simplification of any problem in pelvic surgery in which interruption of the sympathetic nerves to the pelvis seems at first sight to be logical. McCrea and Macdonald in 1934 in considering the rationale of the procedure remarked. It may be said without fear of contradiction that in spite of the attentions of many brilliant workers the functions of the autonomic nervous system are even now only beginning to be understood and it is certain that our knowledge of the nervous control of the bladder is far from complete. It was their impression that although presacral sympathectomy may have a place in the operations on the bladder it would suffer discredit if too much is expected from it. Learmonth (19) also realized that in treating neurogenic vesical dysfunction by presacral sympathectomy he could not hope to restore normal vesical function but thought

TABLE I.—VESICAL PAIN: CLINICAL DIAGNOSIS
AND RESULTS OF PRESACRAL NEURECTOMY
IN 37 CASES

Diagnosis	Cases	Relief of pain		
		Complete	Partial	None
Interstitial cystitis	Typical, including chronic cystitis			
Ureteral tumor	Atypical			
Tuberculous cystitis				
Total				

that it might be well worth while to substitute one abnormal function for another provided the substituted function, although abnormal, was wholly satisfactory in the economy of the patient. Furthermore, Learmonth (19) also raised the question of whether one could alter the economy of any viscus possessing a considerable degree of autonomy in itself merely by the division of its extrinsic innervation. However, despite the several apparent shortcomings of this procedure, he advocated short use in acquired lesions of the sacral segment of the spinal cord or of the pelvic nerves provided the patient was continent and the musculature of the bladder was not completely paralyzed. He also advocated its trial in instances of intractable vesical pain although he remarked that complete relief was obtained only when the pelvic plexus itself was removed. This of course resulted in permanent urinary retention and necessitated the use of a catheter for the remainder of the patient's life. Thus it is evident that presacral neurectomy was far from being an ideal surgical procedure although it offered sufficient encouragement to warrant its trial in selected cases.

POSTOPERATIVE RESULTS

A review of the surgical records of the Mayo Clinic disclosed that presacral neurectomy has been performed in 37 cases of intractable vesical pain and in 35 cases of neurogenic vesical dysfunction. In these two groups of cases the patients were distributed about equally according to sex.

SURGERY GYNECOLOGY AND OBSTETRICS

Irritable pain. The clinical diagnosis and results of presacral neurectomy in the 37 cases of intractable vesical pain are shown in Table I. It is apparent that the operation produced a variable degree of relief of pain in approximately a third of the cases in most of which the relief was only of a partial or temporary nature. It usually lasted several months to a year. In several cases the degree of pain was lessened permanently. In 3 cases there was complete relief of pain. In most of the cases of interstitial cystitis in which there was reduction of pain, the degree of the urinary frequency was only slightly improved. Little improvement was noted in the degree of simple presacral neurectomy in which only a ganglia also were excised.

In 6 of the cases subsequent operation was performed for relief of pain. The following operations were performed: Injection of alcohol into the sacral nerves in 2 cases, suprapubic cystostomy in 2 cases, segmental excision of the bladder in 2 cases, ureterostomy (cutaneous) in 1 case and ureterosigmoidostomy in 1 case.

The treatment of painful cystitis which has been found in recent years to give most relief consists of daily instillations of solutions of silver nitrate in increasing concentration and overdilatation of the bladder while the patient is under anesthesia. In 3 of these cases of intractable pain despite these measures, cystectomy with bilateral transplantation of the ureters into the sigmoid colon was employed.

Neurogenic vesical dysfunction. In the 35 cases of neurogenic vesical dysfunction, presacral neurectomy was performed in an effort to enhance the ability of the patients to micturate. Some measure of permanent relief was obtained in only 6 cases. The relief in these 6 cases however was not entirely satisfactory and in 5 cases it proved to be only partial.

It is apparent that presacral neurectomy has not been of permanent benefit in most of our cases of neurogenic vesical dysfunction. However, the fact that complete relief occurred in 1 case and partial relief in 5 other cases should indicate that section of the sympathetic fibers must have some influence on

found wanting. Although permanent relief resulted in 1 case and temporary improvement in vesical function for as long as a year or more has been noted in several cases, permanent improvement usually was not observed as a result of presacral neurectomy in cases of neurogenic vesical dysfunction. An other factor responsible for the gradual disinterest in presacral neurectomy at least when performed for vesical dysfunction, is the fact that other operative procedures such as transurethral resection of the tissues at the vesical neck, have proved to be of greater effectiveness in providing the desired relief. The changes in the bladder noted in many cases on cystoscopic examination soon after presacral resection would offer corroboration of relaxation of the muscular tissues in the trigone and vesical neck following presacral neurectomy. These findings, together with the postoperative relief of symptoms frequently observed although temporary would indicate that the physiologic premises on which the operation was advocated by Learmonth and Braasch (22) were in a measure sustained.

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THE COMPLICATIONS IN THE SURGICAL HANDLING OF CARCINOMA OF THE LEFT COLON AND RECTUM

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The operative horizon for patients with carcinoma of the large bowel has broadened tremendously within the last decade. Procedures which were hazardous only a few years ago are now available with relative safety and improve in anesthesia preoperative and post operative care surgical nutrition and rehabilitation avoidance of peritonitis etc. have put radical resection within the reach of many hopeless individuals. Large groups of cases are now being reported regularly with low mortality. However this field will always be a difficult and complicated one for curative procedure and one in which any operation is liable to many different complications. It is with this thought in mind that certain complications and problems which arose in the following 4 cases are discussed

into the lower loop. The peritoneum could be seen 2 inches below the skin surface. 'Underneath this the color of the bowel lumen seems better. Nothing was done. Four days later the end of this distal loop became gangrenous and soon sloughed off. There was no sign of any intraperitoneal complication and the upper loop of the colostomy functioned well. Convalescence was otherwise uneventful. When she left the hospital on the 20th day after operation she had to all intents a well functioning single barrel colostomy. The lower segment was not visible.

Two months later the patient re-entered the hospital. The lower portion of the wound below the single-barrel colostomy was opened and the abdomen entered here. A large tongue of omentum was mobilized and freed. Then a very healthy looking lower segment of sigmoid was apparent. It began at the level of the peritoneum where the distal 2 inches had previously sloughed off and there was about 3 inches of distal colon from here to the rectosigmoid junction. This lower segment was mobilized carefully down to the pelvic floor and the two loops of bowel could then be tacked together again as a double barrelled colostomy. A spur crushing clamp was applied and the abdomen was closed. The clamp came off in due time. The patient went home on the 10th day after operation.

Two months later the colostomy was closed by simply freeing it in the subcutaneous fat inverting the dome of bowel and closing the skin. The patient has been well since (now 2 years).

Vascular necrosis of 1 to 2 centimeters of the distal colostomy will not produce fatal peritonitis (8) for the peritoneum seals off and supports the deeper portion of the lumb of bowel. Should the bowel below the peritoneum become necrotic lethal peritonitis may ensue. In this event immediate laparotomy may be indicated. Hence it is important to inspect all colostomy loops within the first 12 to 24 hours after operation.

Another infrequent but very fatal complication of colon resections has been noted by Garlock. The loops having been brought out onto the skin there is subsequent retraction of the exteriorized loop into the abdomen with resulting peritonitis. This condition is due to insufficient mobilization of the bowel

CASE 1. Mrs. Ida K. aged 52 years was first seen in February 1941. Carcinoma sigmoid. Rankin obstructive resection. Necrosis of distal colostomy of double barrel colostomy and later division of the spur with satisfactory closure.

Patient had been constipated for years. This condition had become worse during the past 2 or 3 months and there had been lower abdominal cramps. The cramps had become worse during the past 2 days but they were relieved with bowel movements. X ray films showed an annular constriction in the midsigmoid. At operation there was an annular constricting growth in the upper mid portion of the sigmoid about 1 inch in diameter. Abdominal exploration was done and the wide mobilization of the sigmoid was done and the lesion, including a wide V-shaped apron of mesentery was removed by Rankin obstructive resection. The apex of the resected mesentery was sutured close to the aorta. The two bowel loops were tacked together the peritoneum closed and the bowel amputated above the skin of the abdomen.

That evening it was noticed that the lower loop of the colostomy was dark colored. There was immediate concern for the viability of this loop. A small narrow proctoscope with a light was introduced

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and not to an error in judgment of the blood supply.

With the present day preliminary bowel preparation and lessened danger of peritonitis the major concern in bowel resections is for the adequacy of the blood supply. Certain studies indicate that dividing the bowel $2\frac{1}{2}$ to 3 inches away from the growth on either side is ample lymphatic spread along the bowel surface or lumen does not usually go beyond this distance. It is highly essential to remove a very wide apron of mesentery however. Then it is very easy with a long narrow tongue of mesentery resected, to omit the careful inspection of the bowel ends for blood supply.

CASE 2. Mr. Morris M. aged 68 years was first seen in April, 1943. Large carcinoma of the lower sigmoid with obstruction. Fistula to the bladder. Devine colostomy, then Rankin obstructive resection of the lower sigmoid including a large portion of the dome of the bladder.

There had been some suspicious trouble in the sigmoid in 1936 and an x ray diagnosis of probable polyp of the colon was made. At that time and operation advised. He however sought other advice and refused operation. Apparently from his description he had felt well until recently. For the past 3 to 6 months he had not felt well and said he had lost 50 pounds in weight. There had been mild abdominal pain with some diarrhea and occasional obstructive symptoms.

For the past 2 weeks he had noticed fecal material coming from his bladder on urination. Examination showed a very pale and sallow looking thin man. A large mass could be felt in the lower left abdomen. On urination, there was a rather thick stream of fecal material with some odor. The abdomen was distended and there was complete obstruction. A ray examination showed complete obstruction, no barium going through the sigmoid. It further demonstrated gas in the bladder indicating the location of the fistula.

On April 3, 1943 a Devine colostomy was made in the right upper abdomen. The transverse colon was enormously distended with gas and had to be aspirated. A large mass was felt in the left lower quadrant of the abdomen. A very rapid exploration revealed no further extension of the disease, except on suspicious lump high up on the dome of the liver. The transverse colon was mobilized with some difficulty because of distention and the two loops were brought out in the right upper quadrant and divided for the Devine colostomy. The obstruction relieved in about a week and patient was sent home on May 8, 1943 for rehabilitation. During this time the distal loop of colon was thoroughly irrigated and completely "defunctionated."

On June 5, 1943 the left lower abdomen was explored. A large mass presented in the lower sigmoid region which was adherent to the parietal peritoneum. When this was carefully freed, it was found that the bladder was densely adherent to the mass and the finger could be introduced between the bladder and the sigmoid itself. The left side of the dome of the bladder was resected, an area about the size of a dollar being left attached to the sigmoid growth. There was a hard walled perforation in the center of this which communicated with the bowel lumen. The bladder was then inverted with two layers. The growth was then mobilized easily by dividing the lateral leaf of the peritoneum along the lateral sigmoid wall. The sigmoid was fairly redundant and there was fully 5 inches between the lower end of the growth and the rectosigmoid peritoneal reflection. Wide Rankin obstructive resection was done with wide removal of the apron of mesentery (Fig. 1). The spur crushing clamp was applied 3 weeks later. The sigmoid colostomy was closed July 4, 1943. The Devine colostomy was closed August 30, 1943. Patient then moved his bowels normally and on October 1, 1943 was well although there was still some purulent discharge on urination. He was gaining weight.

Adherence of carcinoma of the sigmoid to the pelvic structures uterus, bladder loop of small intestine, is not a contraindication to radical removal. It is the opinion of most surgeons that these cases are not curable in any large number but the palliation is distinctly worth while and often lasts for 1 or 2 years. It is not usual to be able to resect the bladder successfully with a growth in the sigmoid. In C. W. Mayo's report of 176 resections for carcinoma of the left colon (in which 2 out of 5 were palliative or probably palliative) there was only 1 case in which an attached bladder was resected with the growth although there were several cases in which the bowel had been adherent and adhesions divided.

This is one situation in which the Devine colostomy was valuable. The complete 'defunctioning' of the bowel allows one to resect widely including other viscera with more complete freedom from the fear of peritonitis than we have had heretofore.

CASE 3. Mr. M. G., aged 55 years, was first seen in February, 1943. Carcinoma rectosigmoid. Anterior resection with re-establishment of bowel continuity. Stricture at anastomotic site released by laparotomy and freeing of omental adhesions. Second carcinoma then discovered in splenic flexure. Rankin obstructive resection.



Fig. 1 Case 2 Large fungation carcinoma of lower sigmoid which has extended to and perforated into the bladder. Removed with wide excision of dome of bladder

Patient had lost 25 pounds in the past 6 to 8 months. For the past 3 to 4 months there was heartburn, fullness after fried or spicy foods. He did not feel like eating and felt bad without being able to find out exactly what he meant. He had always had regular bowel movements without a laxative, but during the past 2 months his bowels moved only every other day. For the past weeks there was some lower pelvic pain.

Examination showed a fair sized individual with some evident weight loss. X-ray examination (Fig. 2) showed a constricting lesion just above the rectosigmoid junction. The descending colon and the transverse colon filled very well.

Operation on February 13, 1943, consisted of a left lower midrectus exploratory incision. An annular growth about $1\frac{3}{4}$ inches in diameter with some local involvement of the mesentery but no wide extension was revealed. Its lower end was about 1 inch above the rectosigmoid peritoneal reflection. It was decided to do an anterior resection after first defunctionating the colon with a Devine colostomy. The wound was closed, another incision was made in the upper right quadrant, and the proximal transverse colon was brought into the wound. A spur was formed, the two bowel ends brought out onto the abdomen through two small separate incisions, 1 inch from the main incision. The wound was closed and the bowel divided.

The colon was then thoroughly defunctionated by daily irrigations of the distal segment plus sulfasulzidine per catheter.

Second operation was performed March 9, 1943. The previous wound in the left midrectus was reopened. The sigmoid colon was very clean. It

seemed to be much smaller than normal and the muscular tone was much better. The growth was about 1 inch above the rectosigmoid peritoneal reflection which lay rather deep in the pelvis. The colon was freed in type fashion by incising the peritoneum lateralward then around the bladder and up the mesial leaf. The distal colon and rectum down to the coccyx were then freed from their attachments. When this was done there was 3 inches of bowel below the tumor and the blood supply seemed satisfactory. The superior hemorrhoidal vessels were then divided and the growth in the colon was removed with a margin of about $2\frac{3}{4}$ inches on either side of the growth, great care being taken to preserve the arterial supply of the remaining bowel ends. An end-to-end free style open anastomosis was then made between the lower stump of the rectum and the proximal end of the colon. The anastomosis was performed rather easily with very little spilling. Five grams of sulfanilamide were dropped into the wound. Abdomen was closed with a Penrose drain toward the anastomotic area. Convalescence from this operation was uneventful.

At subsequent office visits, by passing a proctoscope one could see the site of the anastomosis about 4 inches above the rectum. The proctoscope would not pass this point, however, and with some manipulation only a small amount of gas and a slight bit of fecal material could be seen coming through a pin head sized lumen. A barium enema given March 24, 1943, and again April 17, 1943, showed complete obstruction at the site of anastomosis. No barium passed through (Fig. 3). It was decided to explore the abdomen again before an attempt was made to close the colostomy in the right upper quadrant.



Fig. 2. Case 3. Carcinoma of rectosigmoid. Preoperative fluorogram after administration of barium enema, February 8, 1943.



Fig. 3. Case 3. Stricture following anterior resection and end-to-end anastomosis March 24, 1943. Released by laparotomy and liberation of mesocolic adhesions.

On May 5, 1943, the left rectus section was reopened. There was someomentum adherent to the parietal peritoneum but after this was released the abdomen was relatively flat. The sigmoid colon was freed down to the pelvic brim. It was rather densely adherent but after some dissection was freed the colon could be seen as a well-functioning tube. A rectal tube was then passed up from the anus by assistant. It could be felt to go through the anastomosis very easily and was palpable distinctly in the bowels. The pelvic brim was the sigmoid colon. The wound then closed.

It was now thought that the patient's trouble was over and the colostomy might be closed. A barium enema given June 8, 1943, revealed that the distal part of the colon appeared to be of good caliber. The previous constriction seen in the rectosigmoid region apparently had been eliminated. The descending section of the large bowel is well shown and appears to be normal in character. However, the barium entered the splenic flexure a very definite point of obstruction was encountered, and only a small portion of barium could be made to pass the splenic flexure to the transverse colon (Fig. 4). This constriction was also seen by injecting barium through the distal end of the DeWitt colostomy in

the right upper quadrant. X-ray diagnosis as neoplasm of the proximal loop of the splenic flexure. When the original film made before the first operation (Fig. 3) was reviewed it was seen that the distal portion of the transverse colon as it ascended to the splenic flexure was obscured by the descending limb of the splenic flexure and the portion of the colon which now showed that the constriction could not be seen clearly on the first film. After some deliberation it was decided that since the patient's general condition seemed satisfactory it was necessary to remove the second carcinoma at the splenic flexure.

On June 14, 1943, the previous incision in the left midrect was reopened and extended upward. There was a loop of small bowel adherent to the midportion of the abdominal wall which was freed. The splenic flexure was mobilized by incising the lateral peritoneum. There was a large dense stony hard tumor which was nodular and involved about 1½ inches of the bowel just proximal to the splenic flexure. There were some small glands in the mesentery but these were soft. The splenic flexure as mobilized, the greater omentum separated, the mesentery divided, and then a rapid Rankin obstructive resection done. A inch spur was fashioned. The lymph node was normal in microscopic examination.



Fig. 4. Case 3. Barium enema given June 8, 1943, to be certain that the site of stricture in rectosigmoid was satisfactory. Barium passed here without delay. An unsuspected carcinoma discovered in splenic flexure. Compare with Figure 3 taken 4 months before.

Patient left the hospital in 2 weeks. Spur crushing clamp was applied on July 16, 1943, and again on July 30, 1943. The edema subsided and on August 13, 1943, the spur depth was fully $1\frac{3}{4}$ inches and the walls of the bowel seemed smooth. He re-entered the hospital shortly and on August 26, 1943, the left upper colostomy wound was closed, and at the same time the two loops of the Devine colostomy were closed. Convalescence was uneventful. He left the hospital 4 days after the colostomy was closed. Bowels have moved normally per rectum ever since. When last seen September 28, 1943, he was gaining weight, looked well and felt good. There was no abdominal distasis or weakness of either of the wounds. The long wound in the left rectus muscle through which the abdomen had been entered five times, and which now extended from the costal origin to the pubic spine, was well healed (Fig. 5). There was no induration anywhere and no weakness or bulging whatever. Stainless steel sutures had been used.

Emphasis has been placed upon the upward spread of cancer of the rectum by several



Fig. 5. Case 3. Showing abdominal healing after 5 laparotomies. Stainless steel wire used.

anatomical studies since 1930 (2, 6, 11). The evidence is that such spread is generally upward and not downward. Now that preoperative preparation, nutritional deficiencies, protein balance, avoidance of peritonitis and pneumonia are charted and standardized procedures, anterior resection of growths at or just above the rectosigmoid has become popular (3, 4). Growths a short distance above the rectosigmoid are the most suitable for anterior abdominal resection with preservation of the sphincters, and here the Devine defunctioning colostomy finds its chief indication. However, some do an anterior operation for growths lower down (10) for tumors within 10 to 13 centimeters of the anal opening.

Time has not yet elapsed for final statistical evaluation. We have seen a few perineal extensions of far advanced carcinoma of the rectosigmoid. Jones states that a lesion whose lower edge is at the peritoneal reflection of the rectosigmoid or 2 inches above it should have the same operation as those listed under carcinoma of the rectum. For him, that is abdominal perineal removal with a permanent colostomy. He is not satisfied that any lesser

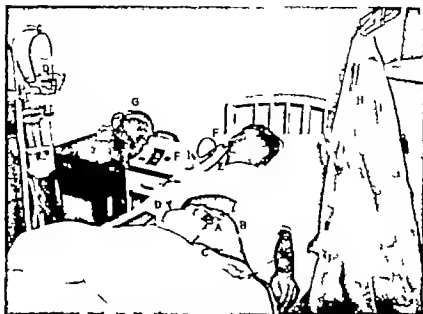


Fig. 6 Case 4. Abdominoperineal resection. Post-operative care. Photograph taken on 6th day after third operation. I Colostomy opening; B enterostomy tube; C urinary catheter with irrigation; D container intravenous glucose and saline, etc.; E Miller Abbott tube with suction (lower small bowel); F Levin tube with suction (stomach); G aspirator for nasal and pharyngeal secretions; H oxygen tent.

procedure with preservation of the anus will show as high a cure rate.

Stricture blocking the anastomotic site is not unknown. Fallis mentions it as having occurred in 3 of 31 cases. One of these required permanent colostomy, the other 2 were kept patent by repeated dilatations. Allen states that stricture requiring tedious dilatation results if the anastomosis is placed below the pelvic floor.

In the case described the stricture was above the pelvic floor and was due to omentum wrapping itself about the anastomosis and apparently was not due to narrowed mucosal lining *per se*.

Some men advocate an aseptic end-to-end anastomosis. This is rather difficult to do deep down in the pelvis. In our experience with this case the free type anastomosis with the open ends of bowel was quite satisfactory and there was no infection or contamination. The reasons for this probably were the absolute emptiness of the bowel plus the partial

sterilization of the contents with sulfasuxidine. Sulfasuxidine as several have noticed and we have also observed will decrease the *Bacillus coli* content of the stool from 10 million per cubic centimeter to 10 thousand per cubic centimeter.

Two new-growths in the colon occurring either simultaneously or within a few months of each other are not unusual. It is unusual, however, suddenly to find the second growth at the splenic flexure after the first one at the rectosigmoid has been finally removed. Whether this was a new development which started in the 6 month interval between the first operation and the removal of the splenic flexure growth or was small and obscured at the first x-ray examination by the descending limb of the splenic flexure we cannot say. This finding simply re-emphasizes the care and attention to detail which management of these cases must have in every phase of treatment.

CASE 4. M. Sam B. aged 54 years, was first seen in August, 1943. Abdominoperineal resection. Mechanical intestinal obstruction. Two postoperative explorations for relief of obstruction. Recovery.

FALLIS, "In very aseptic anastomosis in anterior resection, states "an open anastomosis" just as readily carried out and perhaps permits more accurate suturing.

SALTZSTEIN KELLY CARCINOMA OF LEFT COLON AND RECTUM

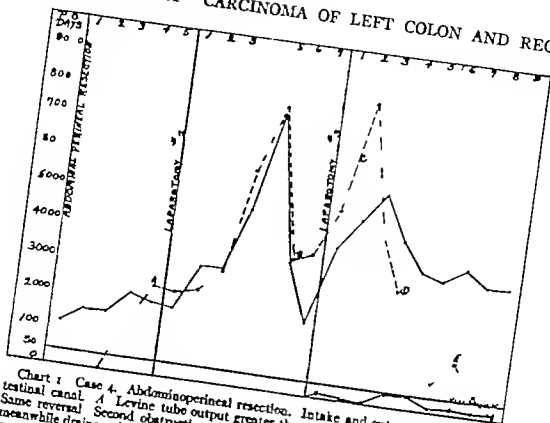


Chart 1. Case 4. Abdominoperineal resection. Intake and output from gastrointestinal tract. A Levine tube output greater than oral intake, first obstruction. B Same reversal. Second obstruction. C Continued reversal after third laparotomy. D Miller Abbott tube suddenly passed pylorus, 90 hours after it had been placed in front of pylorus by fluoroscopic control. Oral intake has been greater than output for 24 hours. E Gastric distention developed while Miller Abbott tube was in lower small bowel, second Levine tube reinserted. — Oral intake. o—o—o, Levine tube output. x—x—x, enterostomy tube output. Miller Abbott

Patient had been well until 3 to 4 months before when he had noticed occasionally a slight streaking of blood in the bowel movement. For the past 6 weeks this streaking had increased, so that he had had several dark black stools and within the last 3 weeks there had frequently been fresh blood in the stool. For the past 6 weeks there had been general malaise and loss of strength also frequent bowel movements with a sense of incomplete evacuation. For 1 week there had been some lower abdominal cramps. There had been no weight loss no constipation.

General examination revealed a moderate sized man in fair health with evident anemia but other wise negative except for the rectal condition. Here examining finger was well within reach of the a dollar which had a curled hard edge and did not seem densely attached to the posterior structures. Microscopic examination revealed carcinoma.

On August 21 1943 a combined abdominoperineal resection was done. There were no glands palpable in the mesentery of the sigmoid. A hard mass was felt high up on the superior surface of the liver under the dome of the diaphragm. It was about 15 centimeters in diameter and beneath the surface of the liver. Since abdominal exploration was otherwise negative and such a liver nodule reached only by the palpating finger was not absolute proof of a

metastatic deposit, the case was deemed suitable for abdominoperineal resection. The operation proceeded uneventfully as was thought. When the pelvic peritoneum was closed it was done so 'very easily except at one place where there was a minimal amount of tension on the suture line. This tension was high up close to the root of the colostomy limb. It was not thought significant at the time. Certainly we have closed the pelvic peritoneum under more tension in other cases.

The posterior resection of the rectum was done partly by the cutting coagulation current. A wide Metcalf pack surrounded by cellophane was packed into the perineal wound.

Immediate postoperative reaction was satisfactory. The perineal pack was removed in 24 hours. Temperature remained at 90 degrees for the first 4 days. However on the 4th day the Levine tube began putting out more than he took in by mouth (clear fluid had been given by mouth) (Chart 1 A).

On the 5th day it was evident that obstruction was present. There was increasing abdominal distention the output through the Levine tube increased and early in the evening large quantities of dark fluid, with a high intestinal odor drained continuously from the stomach. Nothing had come through the colostomy opening. It was decided to explore the abdomen.

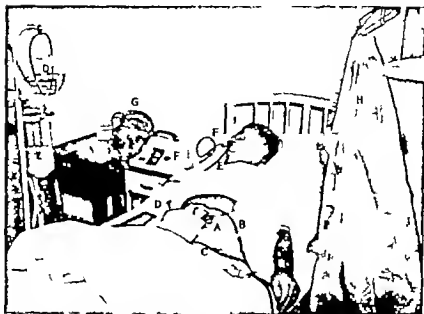


FIG. 6. Case 4. Abdominoperineal resection. Post-operative care. Photograph taken on 6th day after third operation. I. Colostomy opening. B. esostomy tube. C. nasogastric tube. D. continuous intravenous glucose and saline etc. L. (Levin) Abbott tube. Lth. section (lower small bowel). F. Levine tube. Lth. section (stomach). G. aspirator for nasal and pharyngeal secretions. H. oxygen tent.

procedure with preservation of the anus will show as high a cure rate.

Stricture blocking the anastomotic site is not unknown. Fallis mentions it as having occurred in 3 of 31 cases. One of these required permanent colostomy, the other 2 were kept patent by repeated dilatations. Allen states that stricture requiring tedious dilatation results if the anastomosis is placed below the pelvic floor.

In the case described the stricture was above the pelvic floor and was due to omentum wrapping itself about the anastomosis and apparently was not due to narrowed mucosal lining *per se*.

Some men advocate an aseptic end-to-end anastomosis. This is rather difficult to do deep down in the pelvis. In our experience with this case the free type anastomosis with the open ends of bowel was quite satisfactory and there was no infection or contamination.¹ The reasons for this probably were the absolute emptiness of the bowel plus the partial

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CASE 4. Mr. Sam B., aged 54 years, was first seen in August 1943. Abdominoperineal resection. Mechanical intestinal obstruction. T. postoperative explorations. Relief of obstruction. Recovery.

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SALTZSTEIN KELLY CARCINOMA OF LEFT COLON AND RECTUM

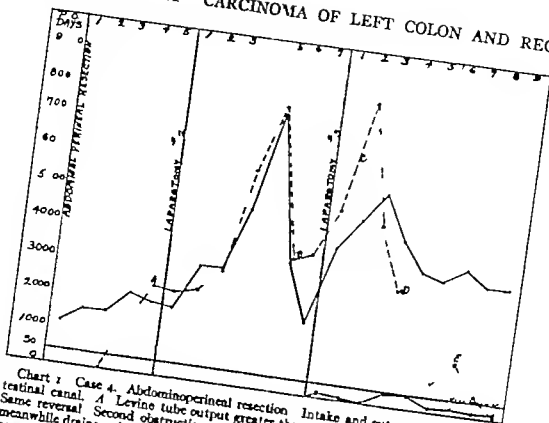


Chart 1: Case 4. Abdominoperineal resection. Intake and output from gastrointestinal canal. A Levine tube output greater than oral intake, first obstruction. B Same reversal. Second obstruction. C Continued reversal after third laparotomy, meanwhile drainage from enterostomy tube started. D Miller Abbott tube suddenly passed pylorus, 90 hours after it had been placed in front of pylorus by fluoroscopic control. Oral intake has been greater than output for 24 hours. E, Gastric distention developed while Miller Abbott tube was in lower small bowel, second Levine tube inserted. — Oral intake — Enterostomy tube output — Miller Abbott tube output

Patient had been well until 3 to 4 months before when he had noticed occasionally a slight streaking of blood in the bowel movement. For the past 6 weeks this streaking had increased so that he had had several dark black stools and within the last 3 weeks there had frequently been fresh blood in the stool. For the past 6 weeks there had been general malaise and loss of strength also frequent bowel movements with a sense of incomplete evacuation. For 1 week there had been some lower abdominal cramps. There had been no weight loss no constipation.

General examination revealed a moderate sized man in fair health with evident anemia but other wise negative except for the rectal condition. Here examining finger was a large ulcer about the size of a dollar which had a curled hard edge and did not seem densely attached to the posterior structures. Microscopic examination revealed carcinoma.

On August 21 1943 a combined abdominoperineal resection was done. There were no glands palpable in the mesentery of the sigmoid. A hard mass was felt high up on the superior surface of the liver under the dome of the diaphragm. It was about 1.5 centimeters in diameter and beneath the surface of the liver. Since abdominal exploration was otherwise negative and such a liver nodule reached only by the palpating finger was not absolute proof of a

metastatic deposit the case was deemed suitable for abdominoperineal resection. The operation proceeded uneventfully as was thought. When the pelvic peritoneum was closed, it was done so very easily except at one place where there was a minimal amount of tension on the suture line. This tension was high up close to the root of the colostomy limb. It was not thought significant at the time. Certainly we have closed the pelvic peritoneum under more tension in other cases.

The posterior resection of the rectum was done partly with the cutting coagulation current. A wide Metcalf pack surrounded by cellophane was packed into the perineal wound.

Immediate postoperative reaction was satisfactory. The perineal pack was removed in 24 hours. Temperature remained at 99 degrees for the first 4 days. However on the 4th day the Levine tube began putting out more than he took in by mouth (clear fluid had been given by mouth) (Chart 1 4)

On the 5th day it was evident that obstruction was present. There was increasing abdominal distention the output through the Levine tube increased and early in the evening large quantities of dark fluid with a high intestinal odor drained continuously from the stomach. Nothing had come through the colostomy opening. It was decided to explore the abdomen.

The second operation was performed on August 26 1943. Under spinal anesthesia the wound was reopened. At the site where the posterior peritoneum had been closed under tension the peritoneum had separated over an area about 1 inch in diameter and at this point the posterior wall was not covered with peritoneum. Over this area the small bowel was stuck tight and there was a small abscess from which about 1 ounce of thick pus was evacuated with suction. The small bowel was dilated above and was narrow below the site of obstruction. The omentum would not stretch sufficiently to cover the denuded area. Because of the patient's condition it was not deemed advisable to do anything further. The bowel was rapidly released and the abdomen closed with through-and-through stainless steel wires. The perineal wound was re-opened and drainage was instituted.

Immediate reaction from this operation was precarious. The pulse remained at 160 for 3 days (Chart 2) and patient was in a semicomatose condition.

Supportive treatment consisted of parenteral fluids, kept at about 3000 cubic centimeters 4 times a day. Urinary output ranged from 500 to 2000 cubic centimeters. Sulfanilamide had been put into the peritoneum (6 gms.) and sulfadiazine was continued intravenously (6 gms. 4 times a day) so that a blood level of 9.3 was obtained. Nourishment was provided by 3000 cubic centimeters of 5 per cent glucose (150 grams) plus about 100 grams of protein administered added to the intravenous fluids, either as amigen (Mead Johnson) or aminoacids (Stearns) (Chart 3).

Patient was quite thirsty and he was given rather large quantities of water by mouth, since these returned immediately through the Levine tube. The 2d day after this he passed gas through the colostomy and 3 days later had one small liquid stool. It was thought our troubles were ended. However no more gas or bowel movement came from the colostomy. On the 7th day after operation on September 3 1943 the Levine tube again was putting out 600 cubic centimeters more than the fluid intake by mouth (Chart 3). Temperature remained between 100 and 101 degrees, pulse 120 and 130, and the patient's condition was only fair. He was irritable, confused, and restless.

On September 9 1943, a portable flat x-ray film showed much gas in the small bowel although abdominal distention was not marked.

The patient was taken to the x-ray department. A Miller Abbott tube was passed, and under frequent fluoroscopic observation it was kept in front of the pylorus for 4 hours, but it made no further progress. It was decided to risk another laparotomy because the obstruction had evidently not been relieved.

At 8:00 p. m. on September 9 1943 the old incision was reopened. The pelvis was occupied by a large mass of distended small bowel. The rent in the posterior peritoneum had become somewhat organ-

ized but there was a granulating surface fully an inch in diameter. There was some greenish inflammatory exudate about this area and two or three loops of small bowel were adherent to it, and covered with some exudate. The remaining loops of small bowel did not have any gross inflammatory exudate about them. They were distended however and were stuck together by plastic adhesions which separated with difficulty and the omentum was spread over their surface rather tightly.

The omentum was mobilized and brought down, and by dividing it into two tongues by longitudinal incision one was able to tack it over the rent in the posterior peritoneum. Because the loops of small bowel could not be separated a rapid Witzel type enterostomy was done. This was brought up through the omentum, and the wound was again closed with through-and-through wire sutures.

Immediate reaction was only fair. Patient was still only semiconscious. The enterostomy tube drained 200 cubic centimeters within the first 24 hours, then drained intermittently and 3 days later drained again another 300 cubic centimeters. For days his duodenal balance was negative by rather large amounts— 600 to 3000 cubic centimeters (Chart 4).

The Miller Abbott tube had been left in situ and functioned as a Levine tube keeping his stomach empty. After 90 hours it suddenly passed the pylorus (Chart 5), then it descended rapidly and evacuated 3000 cubic centimeters. Nutrition was still maintained solely by intravenous injection, 3000 cubic centimeters in 24 hours, which included 15 grams of glucose plus 45 grams of aminoacids. He was still in the oxygen tent and was only partially rational during this entire period.

As soon as the Miller Abbott tube began functioning, he improved. His distention relieved and he became clearer. However on the 6th postoperative day following the 3d operation distention was noticed in the upper abdomen. A Levine tube was inserted through his opposite nostril into the stomach and a second suction apparatus attached (Chart 5). Now the patient had tubes in both nostrils, connected to two separate suction apparatuses on the right side of the bed, an intravenous fluid outfit going into his right arm, an enterostomy tube draining into a bottle on his left side, a permanent catheter in his bladder draining to the left side, perineal dressing with tubes for irrigation, and an oxygen tent (Fig. 6). The Levine tube drained 600 cubic centimeters for 3 days, then the abdominal distention relieved.

On the 8th postoperative day gas was passed through the colostomy. Troubles were not entirely over however. A large tender mass was felt and seen in the right upper abdomen, which area had been sore for 3 or 4 days. After some consideration it was decided to aspirate this mass with a thin

Fluoroscopic results of the fact that the Miller Abbott tube placed well down in the region of the small intestine, used as a pylorus aspirator against intestinal distention, often found necessary to put an additional tube down through the patient's other nostril into the stomach.

SALTSTEIN, KELLY CARCINOMA OF LEFT COLON AND RECTUM

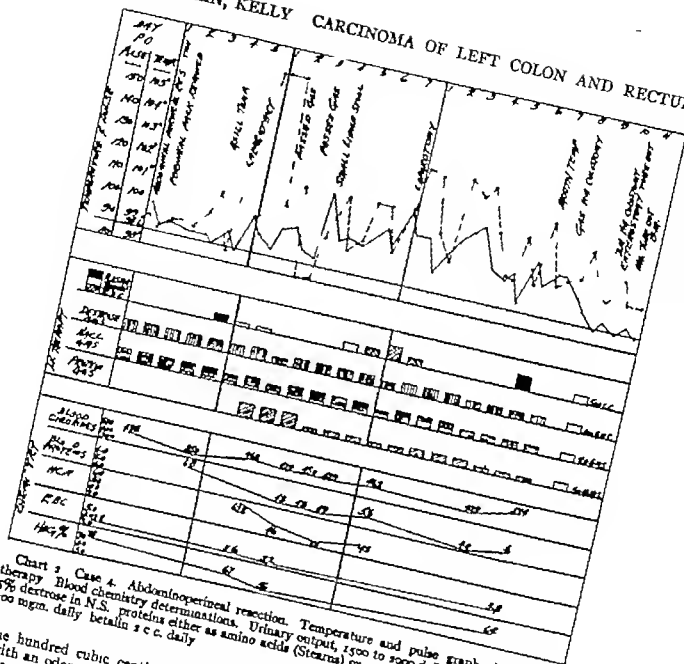


Chart 3 Case 4. Abdominoperineal resection. Temperature and pulse graph. Intravenous therapy Blood chemistry determinations. Urinary output, 1500 to 2000 daily Dextrose given as 5% dextrose in N.S. proteins either as amino acids (Sterna) or amigen (Alfred Johnson) cevalin 300 mgn. daily betalin 2 c c. daily

needle. One hundred cubic centimeters of rather thin fluid with an odor was evacuated. It was felt that this was a distended loop of small bowel which was still somewhat caught in the inflammatory process. This relieved him, and no untoward effects were noticed from the aspiration of the bowel itself. September 12 1943 11th postoperative day after the first bowel elimination. Except for one small liquid stool 4 days after the 3d operation this was exactly 21 days. The Levine enterostomy and 11th postoperative days (after 3d operation) were removed on the 6th, 10th, and 11th postoperative days (after 3d operation).

The chloride balance had been fairly well maintained throughout the entire course (blood chloride 425 to 450 mgm.) Urine output remained stationary. However there was difficulty in obtaining the blood protein level. On September

8 1943 (6th postoperative day after 3d operation) the total blood proteins were 4.0. The next day 1000 cubic centimeters of plasma was given. Patient visibly improved but the following day the blood proteins had been raised only to 5.0 (Chart 3). From then on the convalescence was relatively uneventful. The colostomy functioned very well. There were occasional periods of some distress when tenderness could again be appreciated in the right upper quadrant, but there was no suggestion of any further filling of an isolated loop of small bowel. Patient was out of bed September 13 1943. The wound healed *per primam* sutures were removed on September 18 1943, and there was no weakness in the abdominal wall. Colostomy worked very well with no delay for the past day or two before discharge. Patient ate everything. He was discharged. Résumé Case 4. Combined abdominoperineal resection was done. Pelvic peritonectomy was done.

ly sutured with slight tension. Signs of intestinal obstruction developed 4th and 5th day after operation. Wound was reopened. A gap was found in posterior peritoneal suturing with small bowel stuck to it and localized incision. Obstruction was relieved and feces drained. Colostomy functioned 3 days, and then obstruction developed again. Third operation was performed 6 days later. Small bowel was found matted together in the pelvis, and the site of the rent in the posterior peritoneal closure was still open and granulating, and the small bowel was again adherent to it. Omentum was sutured down here as a large tongue and enterostomy was done. Miller Abbott tube passed the pylorus 90 hours after its insertion, and then bowel finally functioned.

SUMMARY

Four cases of resections of the left colon and rectum are reported illustrating different problems and complications which were encountered.

1. Necrosis of distal colostomy loop after Rankin obstructive resection of carcinoma of the sigmoid; spontaneous separation above peritoneum; refashioning of colostomy spur and successful closure.

2. Fistula between sigmoid carcinoma and bladder; resection of a segment of bladder with the tumor.

3. Anterior end-to-end resection of low sigmoid growth; stricture at anastomotic site relieved by laparotomy and liberation of adhesions; second carcinoma discovered at splenic flexure during convalescence; Rankin obstructive resection.

4. Abdominoperineal resection; postoperative intestinal obstruction (mechanical ileus) from insecure suturing of posterior peritoneum; two postoperative abdominal explorations for release of obstruction; satisfactory recovery.

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LIGATION OF THE THORACIC DUCT AND THE POSTHEMORRHAGE PLASMA PROTEIN LEVEL

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In a previous communication from this laboratory (4) it was reported that after hemorrhage the concentration of proteins in the thoracic duct lymph underwent a considerable increase. On the basis of his finding it was suggested that the lymph rves an important rôle in the compensatory y for fluid hut also as a source of protein eplacement

The present work is an attempt to assay the rôle of the thoracic duct the principal lymph collecting channel, in the maintenance of the plasma protein level after acute hemorrhage

METHOD

Twenty five dogs all in normal nutrition were used in this work. They may be divided into two groups—group I 15 animals in which hemorrhage was instituted after ligation of the thoracic duct group II 10 control animals in which hemorrhage was instituted with the duct intact. In 2 of these animals an incision was made in the neck similar to that in the animals in group I, hut no ligation of the duct was performed

The animals were all weighed prior to the experiment and a sample of blood was taken from the jugular vein for hematocrit and plasma protein determinations by the Barbour Hamilton falling drop method heparin being used as anticoagulant. Anesthesia was induced by injecting 1 cubic centimeter of 3 per cent pentobarbital per kilogram (intravenously). Fifteen minutes after the induction of anesthesia another sample of blood was taken for a second set of hematocrit and plasma protein determinations. The animals

With the technical assistance of Lily Schmidt and Arthur Hallen from the Laboratory of I. Perimental Surgery, New York College of Medicine. The work described in this paper was done under a contract, recommended by the Committee on Medical Research between the Office of Scientific Research and Development and New York University

in group I were then subjected to ligation of the thoracic duct close to its entrance into the left subclavian and internal jugular veins through a low collar incision in the left side of the neck. After closure of the operative wound the animals were bled 25 per cent of the estimated blood volume without ligation of the thoracic duct

The hematocrit and plasma protein values of both groups were again determined 1 to 4 hours after hemorrhage and twice daily thereafter for a period of 9 to 13 days. The post hemorrhage diet of the animals in both groups except for dogs 16 and 22 consisted of water and milk *ad libitum* and the standard kennel diet of purina dog chow adequate both for proteins and calories. Dog 16 belonging to group I and dog 22 to group II were placed on a nitrogen free diet throughout the course of the study in order to determine the influence of diet on the course of the plasma protein curve

RESULTS

Effect of anesthesia Prior to the administration of the anesthetic agent the initial hematocrit readings ranged between 45 and 55 per cent the specific gravity of the plasma averaged 1.0250 and the plasma protein level averaged 6.15 grams per cent. Following the induction of anesthesia, there was an average fall in the hematocrit readings of 5 volumes per cent in all the animals of both groups. The effect on the specific gravity of the plasma varied. In 11 animals there was a slight drop in 10 no alterations occurred and in 5 there was a slight rise

Effect of hemorrhage on hematocrit values In all cases the hematocrit values continued to fall after hemorrhage there being an average 15 per cent volume decrease within 24 hours. The hematocrit value continued to decline on subsequent postoperative days in all cases except 1 in group I and 2 in group II which

TABLE I.—PLASMA PROTEIN PATTERN FOR GROUPS I AND II

Time	Peak of decline No. of animals—%	Incipient rise No. of animals—%	Return to normal No. of animals—%	% return N. of animals—%
A. Thoracic duct ligation followed by hemorrhage—				
24 hrs.	3—12.5			
days	20—66.6	— 6.7		
3 days	— 6	2—12.5		
4 days	2—6.7	2—12.5		
5 days	1—6	2—12.5		
6 days		— 6	— 6	
7 days			— 6.7	
8 days		1—6.7		
9 days			2—25.0	
10 days			2—50	
11 days			— 6	
12-14 da				2—50.0

B. Hemorrhage without ligation of the thoracic duct—

1 hrs.	2—20			
hrs.		2—20		
hrs.	4—40	1—10	1—10	
days	2—20	1—10	2—20	
3 days		—20	—20	
days				
days			1—20	

demonstrated an average rise of four volumes per cent, about the 9th to 11th day. The average total fall of hematocrit values for all groups was 18 volumes per cent.

Effect of hemorrhage on the plasma protein level. The behavior of the plasma protein curve followed two distinct patterns each represented by one of the groups.

In group I it is seen from Table I that the plasma protein concentrations continued to decline to a minima in 2 to 3 days posthemorrhage, the minima averaging 0.6 to 1.8 grams per cent. The curve then began to rise by about the 5th day in all but 1 of the animals (86.6%). Most of the animals reached normal on the 9th and 11th day (66.6%). Four animals (36.6%) showed no recovery of the plasma protein level even after 13 days of observation. In only 2 cases (13%) did the specific gravity of the plasma return to the prehemorrhage level earlier than the 9th day. Animal

18 which was on the nitrogen free diet, followed the typical pattern of the other animals of this group.

In group II (Table I) the fall in plasma protein concentration occurred sharply within the first 48 hours with no further decline thereafter. In 3 of the 10 animals, there was a definite trend toward normal beginning in 6 to 12 hours after hemorrhage. The rise had begun within 24 hours in 8 of the 10 cases (80%). 3 (30%) returned to normal within 24 hours, and 6 (60%) within 48 hours. In only 2 animals was there a delay of 5 days. It was also noticed that all animals of this group were definitely more active than those of group I from the 3d to 8th day after. Animal 22 in this group with the nitrogen-free diet showed the same group pattern reaching normal within 28 hours.

In addition, there were 3 other animals originally subjected to the same operation as those in group I but they were not included in Table I because 2 had postoperative infection, and 1 had died 5 days after operation from secondary hemorrhage caused by a slipped ligature of the femoral artery. The first 2 animals were killed during the 2d week, at which time autopsy showed dilation and enlargement of the lymphatics of the thorax and abdomen but no chylothorax or chyloperitoneum. The cisterna chyli was intact in both. Autopsy of the 3d dog 5 days after operation, revealed similar findings.

Additional experiments. Three animals from group I 12 weeks after the thoracic duct ligation and first hemorrhage were subjected to a second hemorrhage. The plasma protein pattern this time resembled that of the animals of group II. Their results are included in group II.

Figure 1 is a chart showing two sets of curves (a) hematocrit and plasma protein levels after thoracic duct ligation and hemorrhage, and (b) that following hemorrhage in one of the dogs of group II. Figure 2 is a chart of the same dog of group I showing curve of second hemorrhage 12 weeks later.

OBSERVATIONS

The striking difference in the pattern of the return of the plasma protein curves in the

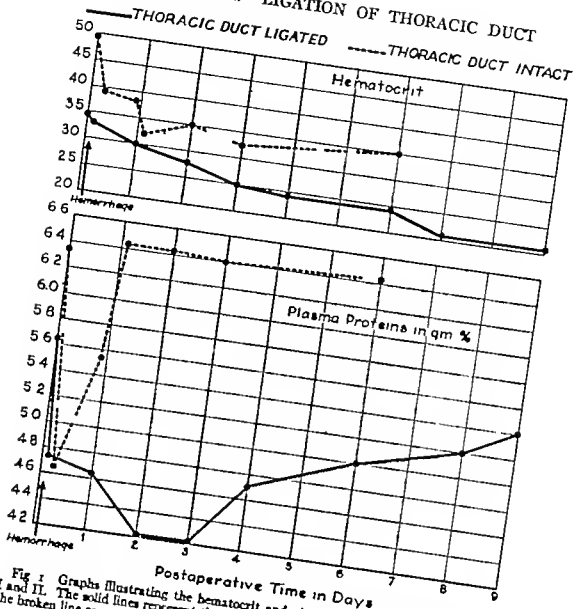


Fig. 1. Graphs illustrating the hematocrit and plasma protein patterns of groups I and II. The solid lines represent the curves of a dog with thoracic duct ligated and the broken line represents the curve of a dog with thoracic duct intact.

first two groups of animals suggests the importance of the thoracic duct in the plasma protein economy of the body. There are 3 explanations for this difference. First the thoracic duct is the main pathway for (a) the return of proteins from the capillary filtrates back into the blood stream (b) for the transfer of depot proteins from such important protein depot organs as the liver. The acute blockage of this pathway therefore would handicap the return of the plasma protein to a prehemorrhage level. The factor of the development of collateral circulation of the principal lymphatic pathways as has been shown by Lee to take place in 7 to 14 days may account for the return to a prehemorrhage level in 8 days or over. The development of

collateral circulation may also explain why the 3 dogs in group I which were again subjected to hemorrhage in 12 weeks followed the plasma protein curve of the dogs in the control group.

The second explanation is that the ligation of the thoracic duct in some way prevented the absorption of foodstuffs from the alimentary tract with consequent inability of the animals to replace lost blood proteins. This explanation however does not sound plausible for several reasons. In the first place the work of Whipple (2) and of Weech and their co-workers shows that after plasmapheresis the plasma proteins are restored from protein reserves in the body mostly from the liver. In the second place Van Slyke (5, 6) and

SURGERY GYNECOLOGY AND OBSTETRICS

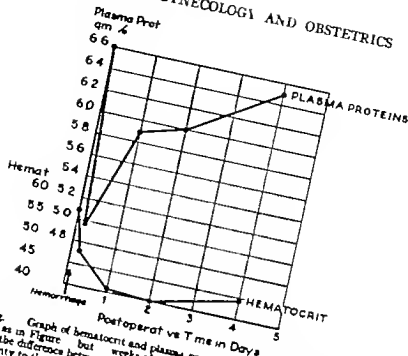


Fig. Graph of hematocrit and plasma protein behavior for same group I dog as in Figure but 7 weeks after ligation and division of thoracic duct. Note the difference between these curves and those of group I, Figure also similarly to those of group II Figure.

Delannay have shown that amino acids are absorbed not by lacteals into the lymphatics but by capillaries directly into the portal circulation.

The third possible explanation is that blood volume changes in the 2 groups follow two different trends i.e. following hemorrhage the thoracic duct ligated animals have a hemodilution for at least 8 days after hemorrhage while in intact animals, the hemodilution disappears in 48 hours. If this disappearance were the case the hematocrit values would reflect a similar picture which in fact did not occur.

SUMMARY AND CONCLUSIONS

The posthemorrhage hematocrit and plasma protein values were determined in 2 groups of dogs: 1 with the thoracic duct ligated and the other with the thoracic duct intact. In the group with the intact thoracic duct the prehemorrhage level of plasma proteins

was achieved in from 24 to 48 hours. In the group with the thoracic duct ligated this level was not reached until after 8 days. On the basis of this finding and on the basis of the finding previously reported of increase in protein concentration in thoracic duct lymph following hemorrhage it is postulated that the thoracic duct and therefore the lymphatic system is an important pathway not only for the return of proteins from the capillary filtrate to the blood but also for the mobilization of proteins from protein depots in the body.

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THE LOCAL EFFECT OF TOPIC ANESTHETIC DRUGS ON THE MOTILITY OF THE GASTROINTESTINAL TRACT OF THE HUMAN AND THE DOG

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Chicago, Illinois

The local effects of topic (or local) anesthetic drugs in the treatment of sprains and fractures have been studied extensively by LeRiche and corroborated by other authors (14-16). The injection of topic anesthetic drugs into such lesions may diminish or abolish the pain the swelling and the reflex contracture. The explanation of this effect is that pain receptors and afferent branches of reflex arcs including those of axon reflexes are anesthetized. Thereby not only pain but also the vicious circle that leads to progressively increasing swelling and rigidity may be abolished.

In a manner similar to that noted in the skeletal muscle the smooth muscle of the gastrointestinal tract may react with spasm to irritants or lesions. The abnormal stimulus may be of various origin: traumatic mechanical, vascular, thermal, chemical, topical allergic, neurogenic or psychogenic and experimentally electrical. In addition to spasm the abnormal stimulus will produce increased motility in the area affected.

Gastrointestinal motility is regulated by short and long reflex arcs of the sympathetic and parasympathetic nerves and by the myenteric plexuses. Gastrointestinal pain is transmitted largely through the sympathetic nerves; it is usually due to swelling of the submucosa to overdistention or to forceful contractions. The intestines contain local reflex arcs. Bavliss and Starling were the first 45 years ago to describe that the action of the musculature of the intestines is in part dependent on the impulses from within the gut itself through the intermediation of the local nervous system.

From the Department of Gastrointestinal Research of Michael Reese Hospital. Aided by a grant from the Nelson Morris Fund. The Department is in part supported by the Michael Reese Research Foundation.

Sensory receptors in the mucosa and subserosa connect with the intramural ganglion cells and these in turn connect with motor fibers to the local musculature. Thus the mechanism for local intrinsic spasms exists independent of long nerve connections. Stimulation of the mucosa produces contraction of the overlying musculature; a local myenteric reflex (1, 3, 10, 18, 19). Axon reflexes may also play an important rôle (10).

Attempts have been made to reduce the effects of normal or abnormal stimuli in the gastrointestinal tract but no systematic work on the effects of topic anesthetic drugs on the motility of the gastrointestinal tract of the intact human or animal has been done as far as we were able to ascertain. The following publications have some bearing on our problem.

Raiford and Muhlen used extensorized denervated segments of small bowel engrafted into the abdominal wall. Stroking the mucosa of these segments produced muscular contractions. Topical application of cocaine blocked this reflex, but did not alter the muscular response at the same point to a stimulus applied outside the cocaine area. They concluded that cocaine did not prevent contraction of the muscle but abolished the receptivity of the mucosa to mechanical stimuli.

Cohnheim, Kestner and his collaborators have shown that novocainization of a segment of intestinal mucosa abolished reflexes originating from that area (5, 6, 7, 17).

Lenz found that a novocain enema prevented the purgative action of anthraquinone derivatives given by rectum to cats (12).

Bayer reported that larocaine abolished pylorospasm and relaxed the stomach in cases of gastric ulcer by the paralysis of sensory fibers

TABLE I.—SUMMARY OF DEGREE AND DURATION OF LOCAL INHIBITORY EFFECTS OF TOPICAL ANESTHETIC DRUGS ON GASTRO-INTESTINAL MOTILITY OF DOGS

	Drugs in signs	No. of Expts.	Depression of motility	
			Degree*	Duration, min.
Irritables	Betraya	100		
	Metocaine	100		
		100		
	Transmitine	15		
Droppers	Betraya	100	3+	10-20
		100	1-2	
			(T)	10-20
	Diethane	100		
	Metocaine	10	1	10
		100		1
	Procaraine	100	1(T)	10-20
	Procaraine	10		1-20
		10	1	1
		100	1	10
Droppers	Transmitine			
		1	1	10-20
	Transmitine GH	1		10
Irritables	Betraya	10	1-2(T)	1-20
	100 & 100		1(T)	
	100 & 100		1(T)	
	Metocaine	10		
		10		
		10		10
		10	1	10
		10	1	10
	Procaraine	10	1(T)	10-20
	Procaraine	10	1-2	10
Irritables		10		1
		10	1	10
		10	1	10
		10	1	10-20
	Transmitine		1-2	10
	Transmitine GH		1-2	1
		10		
		10	1-2(T)	10
Irritables	Betraya	100	1(T)	
	Metocaine	10		10-20
		100		

TABLE I.—SUMMARY OF DEGREE AND DURATION OF LOCAL INHIBITORY EFFECTS OF TOPICAL ANESTHETIC DRUGS ON GASTRO-INTESTINAL MOTILITY OF DOGS—Continued

	Drugs in signs	No. of Expts.	Depression of motility	
			Degree*	Duration, min.
Irritables	Procaraine	10	1	10
		100		10-20
	Transmitine			10
		1		10
		1	1	1
		1		10-20
		10	1	15
		1	1	10
		10	1-2	10-20
	Betraya	100	1(T)	
Irritables		100	1(T)	10-20
	Metocaine	10		
	Procaraine	10		10
	Synthesia	10	1	10
	Transmitine	10		10-20

*Degree of depression.

(T) Transient effect.

Slight drop in tone, height of contraction reduced approximately

one-quarter.

Drop in tone, height of contraction reduced approximately one-half.

Definite drop in tone, height of contraction reduced approximately

three-quarters.

Definite drop in tone, height of contraction reduced approximately

four-fifths.

† Marked drop in tone, no contractions.

‡ =Tone.

and local reflex arcs in the gastric mucosa. He reported to have used larcaine successfully in the treatment of acute gastric ulcers.

In a great number of *in vitro* studies on isolated strips of intestine the effects of topical anesthetic drugs have been variable (1, 4, 8, 20, 21) and we feel that the results of *in vitro* experiments have little bearing on our problem.

The work presented here was based on the idea that interruption of reflex arcs in the gastrointestinal tract in conditions of local inflammation and swelling and local pain and spasm could be expected to be beneficial for the same reasons assumed by LeRiche to be beneficial in the case of sprains and fractures. Therefore, the present work was undertaken the first phase being a study on the effect of

TABLE II.—SUMMARY OF THE LOCAL EFFECTS OF TOPICAL ANESTHETIC DRUGS ON GASTROINTESTINAL MOTILITY OF DOGS

Balloons in.	Metyraline*	Pantocaine	Botyn	Procaine	Trametin	Trametin oil	Diothase Syntropin	Water or Saline
adrenals	++	+	±					
pancreas	++++	++	+	++++	(+)			
esophagus	++++(+)	+	(Spasm)	++++		o(+)(+)+	D +	
	o+		++	++++	+	o+		
			(?)	++++				
stomach, intestines				o(+)(+)(+)+				
	expts		expts	++++				+
	expts (+)		expts	+				
	expts +	expts +	expts +	expts (+)	1 expt.	expts o	± +	o
	3 expts +	4 expts +	5 expts +	3 expts (+)	3 expts (+)	expts (+)		no expts
		expts +	expts +	o expts +	expts +	expts +		expts +
			expts +	1 expt.	1 expt.	1 expt.		

*Each sign in the columns below the drugs signifies one experiment.
 (+) = Questionable inhibition; ++ = Inhibition; +++ = Inhibition and toxic effects; -N = Inhibition; ± = No inhibition and toxic effects.

topic anesthetic drugs on gastrointestinal motility

METHODS

Gastrointestinal motility was recorded with carbontetrachloride-oil (specific gravity 1.5) manometers. Single or double rubber balloons were inserted into the gastrointestinal tract. In the case of a single balloon used in the tests on the human a thin catheter was attached to the rubber tube of the balloon and just above the balloon the topic anesthetic drug solutions were injected through the catheter against the balloon. In animal experiments on the intestines a double balloon system with three tubes was employed. The two balloons were about 1 to 4 centimeters apart and recorded their pressures separately. The third rubber tube opened between the two balloons and after withdrawal of all fluid possible the test solution was injected through it thus the mucosa at the balloon was exposed to the nearly full concentration of the drug. This arrangement yielded more constant results than the single balloon method. In all experiments except one prolonged control tests without injection of drugs or with injection of water or 0.9 per cent saline were performed and in the test experiments sufficient control motility was allowed before injection of a drug. In most experiments gastrointestinal motility was stim-

ulated by marked overdistention of the balloons. In a few experiments on the dog gastric motility was produced by the subcutaneous injection of small doses of prostigmine. For the study of motility of the stomach only one balloon was used.

In the test on the human 4 healthy subjects and 2 convalescent patients with a normal gastrointestinal tract was employed. All subjects were in fasting condition. Gastric duodenal jejunal or colonic motility was recorded. The procedure in the tests on duodenal jejunal motility was similar to that of duodenal intubation and the position of the balloons was checked by fluoroscopy. In the experiments on the colon the balloon was introduced through the rectum into the lower sigmoid.

In the first series of experiments on the dog healthy unanesthetized animals with a metal tube gastrotomy were used for gastric duodenal and jejunal motility. All animals were starved for 12 hours before the test but had access to water. The animals had been trained to lie on the table unrestrained and the taking of rectal temperatures or the giving of intravenous injections did not disturb them. The balloons were introduced through the gastrotomy tube and their position in the intestine was checked by fluoroscopy. One healthy dog with a cecostomy was used similarly the

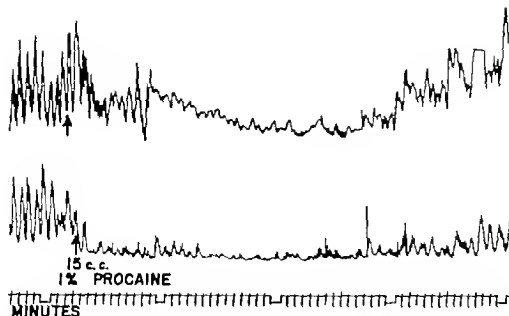


Fig. Colon motility. Unanesthetized, trained normal dog. Two balloons have been introduced into the lower colon through the rectum. Both balloons registered motility separately. The upper tracing is from the proximal balloon and the lower tracing is from the distal balloon. Both balloons were overdistended, and prolonged continuous motility was obtained prior to the administration of the drug. The use of 3 milligrams of procaine in 5 cubic centimeters of air produced an inhibition graded 4 in Table I lasting approximately 30 minutes.

balloons being introduced into the ileum. In other dogs the balloons were introduced into the colon through the rectum.

Acute experiments were performed on anesthetized dogs with balloons inserted at various levels of the gastrointestinal tract taking simultaneous records of the motilities. In these experiments the solutions of the topic anesthetic drugs were injected either at the balloons or far away from the balloons into a lower segment of the intestine or intravenously in order to differentiate between their local effects and their effects via the blood stream or by way of long reflex arcs.

In the experiments on the human and on the dog the drugs to be tested and the water controls were of small volume between 5 and 40 cubic centimeters of water or saline and the fluids were warmed before instillation. We had found in the dog that warming of solutions to about body temperature was essential because cold solutions would produce intestinal motility at times which seemed to be due to the temperature of the solution only. The material was instilled slowly in order to

avoid effects of sudden distention of the intestine. In a number of chronic experiments on the dog the test drugs were given also intravenously.

The following drugs were employed butyn sulfate[†] diethane hydrochloride metycaine hydrochloride pontocaine hydrochloride procaine hydrochloride syntropan phosphate traneptine hydrochloride and transtine 6H.

RESULTS

Experiments on the dog were done first so that a more thorough study could be made on the effectiveness and toxicity of the drugs than was possible in the human. The experimental technique was also developed first in the dog. Human experiments were used to confirm the most important findings. The acute and chronic experiments in the dog have been tabulated together in Table I because the results were similar in both groups. This table shows the doses of the drugs used, the degree and duration of the inhibition obtained and the site of introduction of the drug in the gastrointestinal tract. Most of the

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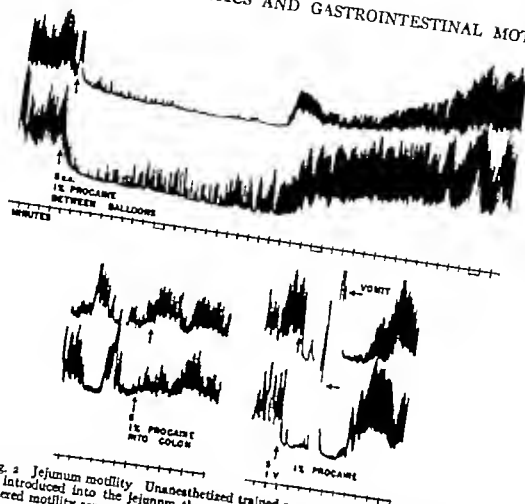


Fig. 2 Jejunum motility Unanesthetized trained normal dog. Two balloons have been introduced into the jejunum through a gastrostomy cannula. Both balloons registered motility separately. The upper tracing is from the proximal balloon and the lower tracing is from the distal balloon. Both balloons were overdistended, and prolonged continuous motility was obtained prior to the administration of the drug. The administration of 50 milligrams of procaine instilled between the balloons was followed by a distinct drop of tone and depression of motility lasting 50 to 75 minutes (see Table III, experiment No. 17). The same dose of procaine instilled into the upper colon through a thin catheter introduced through the rectum had no effect on motility. The intravenous injection of the same dose of procaine was followed by a rather short period of depression of jejunal tone and motility and the dog was nauseated and vomited. The nausea and the vomiting *per se* may explain the short inhibition of jejunal motility.

drugs tested caused definite inhibition of strong motility in the duodenum, jejunum ileum and colon however none of the drugs had any effect on gastric motility. In a number of tests butyn pontocaine and trasentine 6H caused toxic reactions consisting of a drop of blood pressure in the acute experiments (fatal in a few animals) and vomiting restlessness and excitement in the experiments on the unanesthetized trained dogs. These drugs therefore were not used in our tests on the human.

All results on the dog are summarized in Table II. Pontocaine and butyn produced in some experiments spasm of the intestine

either immediately without a preceding depression or following a depression of motility. Butyn in the doses employed seemed to be most toxic. The drugs which showed no toxic effects and which produced most inhibition of intestinal motility when applied topically were procaine metycaine and trasentine. Procaine appeared to be the most reliable drug as it produced depression of intestinal motility in all experiments. This drug was chosen therefore for most tests on the human.

In the last column of Table II the controls with water or 0.9 per cent saline solution are listed. Depression of intestinal motility was seen in only 1 out of 21 tests.

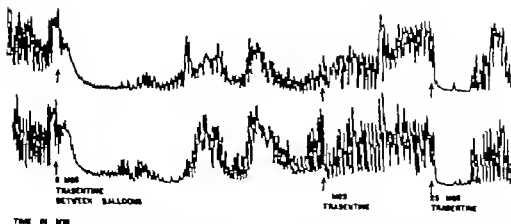


Fig. 3. Ileum motility. Unanesthetized, trained normal dog. Two balloons have been introduced into the ileum through a cecostomy. Both balloons registered motility separately. The proper tracing is from the proximal balloon. Both balloons were overdistended, and prolonged continuous motility as obtained before the administration of the drug. Five milligrams of transientine instilled between the balloons was followed by distinct drop of tone and depression of motility graded 4, and lasting 90 to 4 minutes (see Table III, experiment No. 18). The intravenous injection of the same dose of the drug had hardly any effect on the ileum motility compared with the effect of local application of the drug at the balloons.

Figure 1 represents a typical experiment on the colon of the unanesthetized dog. One per cent procaine solution to an amount of 15 cubic centimeters was instilled between the balloons and was followed by definite and prolonged inhibition.

A series of experiments was performed in order to analyze the mode of action of the drugs. If we were dealing with a local (topical) surface anesthetic effect the introduction of the same drug into another segment of the bowel away from the balloons should have no effect on the intestinal motility at the site of the recording balloons. Figure 2 illustrates a typical experiment. Procaine when injected between the balloons recording the jejunal motility produced a marked inhibition of motility but the same dose of the drug introduced into the colon had no effect on the jejunal motility. However when procaine was injected intravenously it produced a toxic inhibition of the motility for a few minutes. This was overcome by the use of a smaller dose of a less toxic drug. Figure 3 shows this in an experiment on ileum motility. A small dose of transientine produced a marked inhibition of motility when introduced between the balloons and no appreciable effect when the same dose was given intravenously. An intravenous

injection of five times the initial dose produced a sharp inhibition but for a relatively short time. Table III summarizes all the experiments of this type and the data indicate that in every experiment in which a distinct local inhibitory effect was obtained at the site of the balloons, the intravenous injection or the introduction of the same drug into distant parts of the intestine was followed by relatively slight and short inhibition.

The tests on the human were more difficult technically than the animal experiments because the introduction of the balloons and their retention over prolonged periods of time in order to obtain sufficiently long control tracings were not successful with each subject. We have been able however to perform 10 tests on 6 subjects.

The results were as follows:

Stomach

1. 500 mgm. procaine in 40 c.c. water—no effect.
2. 300 mgm. procaine in 30 c.c. water—no effect.
3. 300 mgm. procaine in 30 c.c. water—drop in tone, motility abolished for 1 hour.

Distal small

4. 400 mgm. procaine in 30 c.c. of water—distinct drop in tone; motility abolished for 30 minutes.

Jejunum

5. 500 mgm. procaine in 35 c.c. of water—slight depression of motility.

6. 500 mgm. metyraline in 17 c.c. of water—same as object vomited.
7. 500 mgm. procaine in 40 c.c. of water—distinct depression of tone and motility for 30 minutes (see Fig. 3).
8. 750 mgm. metyraline in 30 c.c. of water—no effect.

Colon

9. 20 mgm. procaine in 16 c.c. of water—no effect.
10. 300 mgm. procaine in 15 c.c. of water—abolition of activity for 20 to 30 minutes.

In test No. 3 gastric motility stopped 10 minutes after instillation of the procaine solution and did not return for 2 hours at which time the test was terminated. In test No. 4 control motility had not been particularly strong. The patient experienced some epigastric pain apparently from the distended balloon in his duodenum. This pain disappeared following the instillation of the procaine into the duodenum, and it reappeared when duodenal motility had returned 20 minutes later. With one exception stated above tone and motility returned to or near control levels when the effects of the drugs wore off. Metyraline was ineffective in one test and produced a questionable inhibition in another test. Vomiting occurred once with 500 milligrams of metyraline.

Figure 4 represents a typical record of inhibition of intestinal motility with procaine (see human experiment No. 7). Following a latent period of approximately 2 minutes tone and motility were depressed for about 30 minutes.

ANALYSIS

The results reported here demonstrate 3 facts. First, topical anesthetic drugs may produce a local inhibition of intestinal motility and tone. Second, this local motor inhibition may be much stronger than the effect of the intravenous injection or of the introduction of the drug into a distant segment of the intestine. Third, spasmolytic drugs like atropine or syntropan appear to have similar effects, i.e., they may act like a topical anesthetic drug and have a much more pronounced local effect than that following their intravenous injection or their introduction into a distant segment of the intestines.

The local inhibition of intestinal motility with the topical anesthetic drugs probably is affected by anesthesia of the receptors of local reflex arcs and the consequent abolition of the

TABLE III — EFFECTS OF LOCAL AND SYSTEMIC ADMINISTRATION OF TOPICAL ANESTHETIC DRUGS

Experiment N	Drug		Depression of motility	
	In mgm.	Injected to	Degree*	Duration min.
Duodenal motility (balloon in duodenum)				
A (Acute)	Pantocaine	100	Duodenum	3
				30-40
	Hydro	100	Duodenum	
				30-40(T)
A ₂ (Acute)	Procaine	50	Intravenous	
				(T)
	Procaine	50	Duodenum	3
				5-20
		100	Duodenum	3
				10-30
		100	Ileum	3
				5-20
Jejunal motility (balloon in jejunum)				
J ₁ (Chronic)	Procaine	50	Colon	
				30-45
		50	Jejunum	3
				5-6(T)
J ₂ (Chronic)	Procaine	50	Intravenous	()
	Procaine	50	Colon	4
				5
		50	Jejunum	4
				5
		50	Ileum	()
				5(T)
Ileum motility (balloon in ileum)				
L ₁ (Chronic)	Tranexaline	5	Ileum	4
				30-40
		5	Intravenous	
L (Chronic)	Tranexaline	5	Intravenous	4
	Tranexaline	5	Ileum	3
				40-60
L ₂ (Chronic)	Tranexaline	5	Intravenous	3
				5
	Tranexaline	5	Ileum	3
				30-40
C ₁ (Chronic)	Tranexaline oil	5	Intravenous	3
				0-15
Colon motility (balloon in colon)				
C ₂ (Chronic)	Tranexaline		Colon	
				5-30
	Syntropan	10	Intravenous	5
				5-30
C ₄ (Chronic)		10	Colon	5
				5-30
		10	Intravenous	5
				5-30

Degree of depression.

() Questionable effect

1. Slight drop in tone, height of contraction reduced approximately one-quarter

2. Drop in tone, height of contraction reduced approximately one-half

3. Definite drop in tone, height of contraction reduced approximately three-quarters

4. Definite drop in tone, height of contraction reduced approximately four-fifths

5. Marked drop in tone, height of contraction reduced approximately

6. Marked drop in tone, no contractions

T=Test



Fig. 4. Jejunal motility. Normal male subject, 9 years of age, 50 pounds in weight. A single balloon was introduced through the mouth. Its location in the jejunum was confirmed by fluoroscopy. Twenty-five centimeters of 2 per cent procaine solution was injected through this catheter attached to the balloon tube and ending just above the balloon. The tube was then raised with 5 centimeters of water. Not marked drop in tone and motility.

expulsion reflex produced by the distended balloon. This effect must be a local one because the drug did not seem to act as effectively from the blood stream following its intravenous injection. The absence of or the slight effect following the introduction of the drug into a distant caudal segment of the intestine shows that we were not dealing with depression of motility through long reflex arcs or through absorption of the drug into the blood or lymph.

The topic anesthetic effects of some of the spasmolytic drugs have been described (9, 15) but nobody to our knowledge has associated their spasmolytic effect with that of topical anesthesia. If this work can be extended and confirmed we may have to change some of our concepts about the mechanism of action of these drugs.

Our findings may have clinical application. With a Miller Abbott tube in place above the site of obstruction of a spastic ileus, the instillation of procaine or trasantone solution may be tried and the spasm may be relieved. If we think in the terms of the vicious circle associated with sprains, described herein we may also expect a prevention or diminution of swelling of the intestinal mucosa.

We are not able to explain why in no animal experiment and in only one test on the human was gastric motility depressed. It is possible that the sensory innervation of the gastric mucosa is different from that of the intestinal mucosa.

SUMMARY

The effects of topical anesthetic drugs were studied on gastric and intestinal motility and tone of the human and of the dog.

Intestinal motility and tone were inhibited in a great number of tests following the local application of such drugs.

Gastric motility was inhibited in only one test in a human subject, and in none of the experiments on the dog.

Certain spasmolytic drugs have a distinct topical anesthetic effect on the intestinal mucosa similar to that of the well known topical anesthetic drugs.

The local inhibition of intestinal motility and tone by the topical anesthetic drugs and by some spasmolytic drugs is not due mainly to effects via the blood stream or via long reflex arcs, but is due mainly to local action, apparently anesthesia of sensory receptors and abolishment of local motor and tone reflexes.

The possible clinical application of the results observed is discussed.

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THE RELATION OF VITAMIN C TO ANESTHESIA

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 BRADFORD HAFFORD Ph.D.

IN the course of a study concerning the protective action of vitamin C against liver damage (2) it was observed that the state of vitamin C nutrition of guinea pigs materially influenced their response to certain anesthetics which were used as hepatotoxins. Except for one indefinite report (12) a review of the literature revealed no publications dealing directly with the effect of anesthesia on the vitamin C content of blood plasma or the effect of vitamin C deficiency on the response of an animal to anesthesia.

The purpose of this research was to determine (1) the effect of anesthesia on the vitamin C content of plasma and (2) the effect of C avitaminosis on the animal's response to anesthetic agents.

PROCEDURE

The vitamin C content of plasma was determined by the photocolometric method of Miandin and Butler. Six to 8 cubic centimeters of blood was drawn, centrifuged and 2.5 cubic centimeters of plasma used for the analyses. Care was exerted in drawing the samples to avoid hemolysis the presence of which quickly decreased the apparent ascorbic acid content of plasma. These determinations were made immediately after the blood was drawn for in our experience the vitamin C content of whole blood from the dog decreased on standing even in a few hours at 5 degrees C. Samples of blood for analysis were drawn according to the following schedule (1) immediately before

an induction to serve as controls (2) just before a 45 minute anesthetization was terminated (3) 5 to 7 hours after an experiment was begun and (4) a final sample 24 hours after the induction. Additional determinations of plasma C were made 48 hours after anesthesia in one set of experiments.

The anesthetics used in the course of these experiments were diethyl ether, vinylene¹ chloroform and cyclopropane. The first three agents were given by the open drop technique to 8, 6 and 12 dogs respectively. The animals used for the open drop anesthetics were not intubated. None of the animals used in these experiments was given any type of premedication. All the dogs were maintained at light surgical anesthesia for 45 minutes.

Six dogs were anesthetized by rebreathing a cyclopropane-oxygen mixture from a 5 liter rubber bag. They were then fitted with a cuffed endotracheal tube to insure an open airway and were connected through a soda lime carbon dioxide absorbing canister to a 100 liter rubber bag containing a 25 per cent mixture of cyclopropane in oxygen. The animals were maintained on this anesthetic mixture for 45 minutes. In unpremedicated dogs this concentration of cyclopropane produced light surgical anesthesia. Six other animals were anesthetized in the same manner but were maintained for 45 minutes on a mixture of 25 per cent cyclopropane, 10 per cent oxygen and 65 per cent nitrogen.

Closed system anesthesia with diethyl ether was employed for 12 animals. Induction was

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¹ Trademark of Merck & Co. for divinyl ether.

brought about by the open drop technique. After intubation the animals were connected through a soda lime cannister to the anesthetic reservoir which was a Tissot spirometer of 100 liters capacity. Six of the dogs were maintained for 45 minutes on a 4 per cent mixture of ether in oxygen and the other 6 maintained for the same period of time on a mixture of 4 per cent ether, 10 per cent oxygen and 86 per cent nitrogen. This concentration of ether also produced light surgical anesthesia in unpremedicated dogs. The concentrations of the gases were checked repeatedly by analysis.

To study the effect of the vitamin C content of an animal on its response to anesthesia, guinea pigs were used. These were divided into 2 groups. Both groups were placed on a diet of purina rabbit chow checkers¹ known to be deficient in vitamin C but otherwise adequate. Ecker and Pillemar have reported that on this diet guinea pigs showed signs of scurvy in 21 days and that 10 to 20 milligrams of ascorbic acid per day was necessary to maintain optimal plasma concentration of the vitamin. One group was given no vitamin C. The other group of guinea pigs was given 30 milligrams of ascorbic acid daily. The ascorbic acid was made up with half its weight of sodium bicarbonate dissolved in 1 cubic centimeter of distilled water and immediately injected subcutaneously. The weight of the guinea pigs in each group was followed for about 16 days at which time the deficient animals ceased to gain. At that time the effect of an anesthetic on the animals of both groups was studied. A glass chamber of approximately 15 liters capacity was used for these experiments. This was provided with an adequate inlet and outlet for air, the anesthetic being volatilized in the chamber. Vinethene, ether and chloroform were the anesthetics used.

A comparison of the response of vitamin C deficient and adequate animals was made by placing guinea pigs of each group in the induction chamber at the same time and comparing their reaction to the anesthetic agent. While it would be difficult to control the experiment

by direct open drop anesthesia, one can compare by this method the responses of two groups of animals at the same concentration of the volatile agent. The period of anesthesia varied from long enough to induce the deficient guinea pigs to 45 minutes, depending on the comparison to be noted.

RESULTS

The effect of anesthesia on plasma vitamin C. A low control plasma level of ascorbic acid seemed characteristic of dogs maintained on a diet of purina dog chow which was practically devoid of vitamin C. The average of the control values (omitting the B dogs of the vinethene series) listed for 46 dogs was 0.359 milligram per 100 cubic centimeters. It was possible to increase the plasma vitamin C level by the subcutaneous administration of 150 milligrams of ascorbic acid daily for several days as was done for the dogs lettered 'B' of the vinethene series (Table I).

In general, the effect of anesthesia was first to increase the vitamin C concentration in plasma within 7 hours following induction and then to lower its level below the control values within 24 hours. This generalization holds for vinethene, chloroform, ether and cyclopropane uncomplicated by inadequate oxygenation (Tables I and II). From this trend the effects of the different anesthetics vary somewhat.

The actual or real increase in plasma vitamin C expressed in milligrams per 100 cubic centimeters of plasma was on the whole, but not invariably independent of the initial plasma concentration. For this reason, 2 dogs having quite dissimilar control plasma C values but whose mobilization was the same in amount after the period of anesthesia showed a markedly different per cent increase over the control levels. Reflection will make it apparent then, that per cent increase rather than actual increase would be a hazardous basis for the interpretation of these results. Consequently throughout this paper comparisons will be made of the actual increase (mgm. per 100 c.c. of plasma) though the per cent increase is also given in the tables.

Following anesthesia produced by vinethene, some of the animals mobilized ascorbic acid

¹The composition of the diet was as follows: protein, 13.9 per cent; fat, 28 per cent; carbohydrates 44 per cent (including 15.60 per cent starch); calcium, 0.0004 per cent; phosphorus, 0.0004 per cent; potassium, 0.0004 per cent; magnesium, 0.0004 per cent; sodium, 0.0004 per cent; iron, 0.0004 per cent; zinc, 0.0004 per cent; copper, 0.0004 per cent; manganese, 0.0004 per cent; iodine, 0.0004 per cent; selenium, 0.0004 per cent; vitamin A, 0.0004 per cent; vitamin B, 0.0004 per cent; vitamin C, 0.0004 per cent.

to the plasma more readily than did others. At most of them had their highest reading within 5 to 7 hours following the induction (Table I). In only one animal did the plasma vitamin C continue to rise for 24 hours. There was noted an initial fall in the ascorbic acid content of the plasma in 3 of the 12 dogs. Actually, these data represent but single determinations on a number of animals though we have done repeated experiments on each of them. This initial fall was occasionally seen in most of the dogs of this group and may be a part of the response in all of them.

In the case of chloroform (Table I) the mobilization of vitamin C into the plasma seemed to be much more rapid, being greater at the end of the induction in two-thirds of the animals than at the later period. The mobilization of reduced vitamin C into the plasma under influence of vinethene was greater than in the case of chloroform anesthesia (0.37 mgm. per 100 c.c. as compared with 0.175 mgm. per 100 c.c.). Also the fall within 24 hours was greater for vinethene than for chloroform (0.214 mgm. per 100 c.c. as compared with 0.083 mgm. per 100 c.c.). We do not feel justified in making more than this qualitative distinction between the two compounds in this matter because of the marked difference in the average control levels of ascorbic acid in the two series. Chloroform has been known for many years to be quite toxic. Orth, Slovicum, Stutzman, and Meek reported the hepatotoxic effect of vinethene. The greater degree of liver damage following vinethene than after chloroform anesthesia which they observed may explain the apparently greater upset of ascorbic acid metabolism in the case of vinethene.

While ether anesthesia does produce a transient hyperglycemia and glycosuria, both ether and cyclopropane are generally considered fairly innocuous so far as after-effects are concerned. However, from Tables I and II it is evident that the mobilizing effect of ether on plasma ascorbic acid was greater by both open drop and closed system administration than for either chloroform or vinethene. The average of the maximal increase following open drop ether anesthesia was 0.298 milligram per 100 cubic centimeters which was greater than the

mobilization effect of vinethene (0.237 mgm. per 100 c.c.) and 75 per cent greater than for chloroform (0.175 mgm. per 100 c.c.). On the other hand the average fall below normal (0.158 mgm. per 100 c.c.) 4 hours after ether anesthesia was between the corresponding values for chloroform and vinethene (0.081 and 0.14 mgm. per 100 c.c., respectively). The rate of mobilization of plasma vitamin C was slower following ether than following chloroform and is comparable to the rate of increase following vinethene to which agent it is more closely related chemically.

Cyclopropane anesthesia was followed by the least rise in plasma vitamin C (0.131 mgm. per 100 c.c. average) and this occurred at the end of the period of anesthesia. The fall of the plasma level below normal after 24 hours (0.187 mgm. per 100 c.c.) was somewhat greater than for ether.

Closed system anesthesia with both cyclopropane and ether was undertaken to evaluate the part inadequate oxygenation might play in the results (Table II). While with the open drop technique the dogs were kept in light surgical anesthesia and apparently well oxygenated we believed that our results might possibly be interpreted as being due to inadequate oxygen supply to the animals.

In a comparison of two groups of cyclopropane anesthetizations in which 75 and 10 per cent oxygen was supplied, certain differences were evident. When a high percentage of oxygen was used the mobilization of vitamin C was immediate. The plasma C level then fell off to below the controls at the end of 24 hours. In the case of the dogs administered 10 per cent oxygen in the anesthetic mixture the rise in plasma C levels increased more gradually and persisted over 24 hours falling to or about the control levels only after 48 hours. A secondary fall in plasma ascorbic acid level did not characteristically occur within 2 days. When 10 per cent oxygen was administered with the same amount of cyclopropane as before, nitrogen being used as the diluent, the animals were deeply cyanotic during the whole of the anesthetization and had to be watched carefully to avoid acute cardiac failure. There seemed to be an increased fragility of the cells for there was experienced considerable diffi-

TABLE I.—THE EFFECT OF 45 MINUTES OF VINETHENE, CHLOROFORM, AND DIETHYL ETHER ANESTHESIA, OPEN DROP ADMINISTRATION ON THE PLASMA VITAMIN C LEVEL OF DOGS

Dog	Plasma vitamin C in mgm. per cent								
	Control	Fasted	Fasted	Fasted 3	Maximal increase			Decrease	
		End of anesthesia	57 hrs after induction	54 hrs after induction	Actual mgm.	Per cent	Period	Actual mgm.	Per cent
Vinethene									
1A	38	412	366	18	21	55		277	72.5
2A	24.5	38	38	176	260	1065		247	14.5
3A	553	715	656	89	121	21		364	52.5
4A	47	258	47	26	18	38		266	64.7
5A	290	254	690	21	408	38		277	68.5
6A	222	18	499	3	262	26.7	3	208	80
7A	267	266	447	21	150	1.8		33	12
8B	208	26	286	266		12		619	67
9	229	320	520	6	79	44.7		437	8
10B	807	206		12	23	24		654	8
11	271	298	262		279	24.8		258	22.4
12	236	773	286	298	26			24	6
Average	293				37	69		214	24.7
Chloroform									
13	421	679	264	38	179	42.6		178	40.7
14	27	249	241	205	207	24		209	25
	2.08	38	26	277	18	29		205	24.6
15	248		122	212		26.5		21	7
7	245	268	26	27	242	26		226	19.3
12	244	212	212	200	269	26		208	26
Average	214				17	126.7		204	26.1
Ether									
19	294	293	18	220	26	27		274	23
20	578	256	25	262	262	20		266	20
21	447	297		44	30	24.6		200	20
	210	270	782	22	27	22		262	22
22	226	20	12	226	167	26		208	20
24	23	242	226	209	266	205.5		262	24
	222	22	272	222	29	2		262	24.2
26	206	218		26	22	77.7		266	26.6
Average	296				298	24.2		26	26

culty in drawing blood at the 5 to 7 hour interval after anesthetization without obtaining some hemolysis which would of course produce error in the results. However among these

animals only 3 had an apparent mobilization peak at the end of anesthesia. It was observed (Table II) that in the case of these the blood drawn at the 5 to 7 hour period was hemolyzed

some extent, consequently the values they presented were probably too low. The extent of the delayed rise in the animals maintained at low oxygen tension during anesthesia was not significantly different from the extent of the rise when 75 per cent oxygen was used in the case of cyclopropane it was concluded that the immediate mobilization and the fall below the control plasma vitamin C after 24 hours was initiated by the anesthetic agent, not by insufficient oxygenation.

Likewise in closed system ether anesthesia oxygen deficiency was ruled out as a factor in production of the vitamin C effect. In all of the other experiments the dogs supplied with 96 per cent oxygen those supplied with air (open drop) and others with 10 per cent oxygen the maximal mobilization of ascorbic acid was in 5 to 7 hours following induction. If inadequate tissue oxygenation were responsible for the initial rise and subsequent fall in plasma vitamin C one would expect the greatest effect when only 10 per cent oxygen was administered and least change with the mixture containing 96 per cent oxygen. Actually the reverse was true. The greatest mobilization of the vitamin was in the experiments in which 96 per cent oxygen was given with ether and least mobilization of plasma C when 10 per cent oxygen was supplied and the dogs remained deeply cyanotic for 45 minutes. The fall of the plasma C levels below the control values was about the same for dogs anesthetized by the open drop and the closed system containing 96 per cent oxygen in the gas mixture. Again the fall was least in the case of the dogs rendered cyanotic. These comparisons are based on the actual increase or decrease in the content of ascorbic acid in 100 cubic centimeters of plasma (mgm per cent) (Tables I and II).

The effect of vitamin C deficiency on the response of guinea pigs to anesthesia is more easily described than expressed in tabular form. Forty-two guinea pigs prepared for the experiments in the manner described in the procedure were divided into three groups: (1) 8 adequate and 8 vitamin C deficient guinea pigs were used for the chloroform anesthetics; (2) 7 adequate and 7 deficient animals were

used for vinethene and (3) 6 adequate and 6 vitamin C deficient guinea pigs were used for ether anesthetics. All of the guinea pigs had been on the same basal diet. Representative protocols of the experiments serve to illustrate the effect of the anesthetics on the animals. For any one experiment the concentration of the anesthetic was of course the same for all the animals.

Protocol 1. Ether anesthesia. Animals 1 and 2 of the vitamin C deficient and adequate guinea pig groups were used. When placed in the anesthesia chamber the C deficient animals fell over on their side and became unconscious 5 minutes before those that had received vitamin C. The deficient pigs were much more deeply anesthetized as judged by movements and respiration. After 30 minutes anesthesia the animals having received ascorbic acid were able to right themselves in 10 to 15 minutes sooner than the C deficient animals. The avitaminotic animals were in poor condition 18 hours after anesthesia. The number 2 deficient guinea pig died within 24 hours following anesthesia.

Summary With the use of a slowly induced prolonged ether anesthesia, vitamin C deficient guinea pigs became anesthetized sooner were more deeply anesthetized, and recovered more slowly than the C injected animals. The deficient animals showed prolonged toxic manifestations after the period of anesthetization.

Protocol 2. Chloroform anesthesia. Animals 7 and 8 of the vitamin C adequate and deficient groups were used. The deficient guinea pigs were anesthetized the more quickly and within 5 minutes went into respiratory arrest from which they could not be revived. During this time the number 8 C adequate animal became very lightly anesthetized and the number 7 ascorbic acid injected guinea pig did not fall off its feet. Both of these animals apparently recovered completely 5 minutes after a 10 minute period of anesthesia.

Summary With the use of rapid induction chloroform anesthesia the vitamin C deficient guinea pigs became anesthetized sooner and died at a concentration of the anesthetic agent which produced partial to light anesthesia in the vitamin C injected animals.

Protocol 3. Vinethene anesthesia. Animals 6 and 7 of the vitamin C adequate and deficient groups were used. The concentration of the anesthetic agent was very carefully controlled so that the C adequate guinea pigs were lightly anesthetized, the C deficient animals being much more deeply anesthetized. After a simultaneous 45 minute period of anesthesia for

TABLE II.—THE EFFECT OF 45 MINUTES OF CLOSED SYSTEM CYCLOPROPANE AND ETHER ANESTHESIA, WITH AND WITHOUT ADEQUATE OXYGENATION ON THE PLASMA VITAMIN C LEVEL OF DOGS

Dog	Plasma vitamin C in mgm per cent									
	Control	Period	Period	Period 3	Period	Maximal increase		Decrease in 24 hrs		
		End of anesthesia	2-7 hrs. after induction	24 hrs. after induction	48 hrs. after induction	Actual mgm.	Per cent	Period	Actual mgm.	Per cent
Cyclopropane 25%, oxygen 75%										
27	430	690	146	287		30	51		143	23.2
28	180	384	36	600		493	27		380	209.4 ^a
29	133	7	136	430		305	12.6		299	29.7
30		306	302	36		34	3		76	23
	496	309	3	36		453	14		463	19
31	36	21300	514	300		413			136	16
Average	406					31	27		76	26
Cyclopropane 25%, oxygen 50%, nitrogen 25%										
	230	230	463		54	124	79	3	400	60
34		34	287	611	113	360	49.5	3	400	60
	364	614	11300	43	34	360	44		400	60
36	211	478	234	27	266	34	44		413	3
37	243	613	4000	370	308	287	12.5		400	60
38		493	146	794	245	23	3		79	53
Average	21					160	51			
Ether 45%, oxygen 50%										
39	400	371	773	113		3	60.3			16.5
40	404	454	404	404		48	25.5		270	23
41	300	3830	463	404		383	12		496	
42	444	630	413	305		304			413	10.3
43	6.5	1.300	6.00			49.4 ^a	4 ^a		711	34
44	60	410	490	40	37	530	47.3			
Average	306					440	39.3		140	
Ether 45%, oxygen 20%, nitrogen 35%										
5	413	361	467	3		320	60.3		5	16
46	406	404	40	773		5	20		220	43
47	308	784	340	353		33	6.5		400	60
48		146	344	373		410 ^a	5.4 ^a		4.463	76.3
49	514	308	410	346		195	30		178	24
50	390	401	407	447		407	10.2		400	60
Average	437					53	15.7		407	60

^aNot included in average

sh—slightly hemolyzed

h—hemolyzed

groups the animals receiving ascorbic acid recovered and were apparently normal in 20 minutes. Avitaminotic animals made a slower partial recovery but were dead the next morning after 18 hours.

For purposes of illustration each experiment as herein represented by a different anesthetic agent. The same observations held qualitatively for all 3 agents, ether being apparently the least toxic of the 3 anesthetics to the vitamin C deficient guinea pigs.

To sum up these experiments, it has been observed that vitamin C deficient guinea pigs are not yet showing any manifestations of scurvy (unless cessation of weight gain be considered a sign) were more quickly induced by a given concentration of ether, chloroform or vinylene than were more deeply anesthetized and recovered more slowly if at all than animals that had been injected daily with an adequate amount (30 mgm) of ascorbic acid.

ANALYSIS OF STUDY

The initial mobilization and secondary depletion of plasma ascorbic acid which we observed fits in with the results of others to give an attractive composite picture of the effect of anesthesia on the distribution and excretion of vitamin C. This overall phenomenon can be depicted clearly from available data without the need for speculation as to the more fundamental processes involved.

Our data indicate that the ascorbic acid content of plasma does increase during and for at least 7 hours following anesthetization when any of several agents is used. This effect is qualitatively independent of the mode of induction and the presence of adequate or inadequate oxygenation (Tables I and II). It is interesting to recall at this point that Sherry, Friedman, Paley, Berkman and Rall showed by simultaneous creatinine and ascorbic acid clearances that the tubular reabsorptive mechanism for the vitamin is limited by a low maximal rate so that as the filtration rate exceeds this maximum the excess is excreted in the urine. One would anticipate then that as the plasma vitamin C level increases following anesthesia the urinary output of ascorbic acid would increase. Actually this has been found to be true. In 1935 Zilva noted that when ether

was employed for intravenous injection of vitamin C into guinea pigs the excretion of the vitamin was twice as great as when administered under novocain. Milhorat, Bartels and Toscani and Berain, Lauber and Nafziger have also reported an increased urinary ascorbic acid output following chloroform anesthesia.

The mobilization of vitamin C for repair (5) as the tissues recover from the depressive action of anesthesia on cellular respiration (11) serves as a second factor to deplete the plasma of the vitamin. When the increased excretion and tissue utilization following anesthesia are considered it is quite consistent that we should have found the plasma ascorbic acid levels to be reduced 27% to 48% per cent below the preinduction levels 24 hours after anesthesia. Reflecting this same process are the data of Bowman and Muntwyler. They found that for the first 24 hours after a 2 hour ether anesthetization the ascorbic acid excretion by dogs increased 2 to 5 times. However during the second postanesthesia 24 hour period the vitamin C output was below the preinduction control periods.

Finally, clinical corroboration of these experimental observations on dogs may be deduced from the report by Lund. His data show that within the first 2 postoperative days the plasma ascorbic acid level of patients decreased 30 to 50 per cent and remained low for at least 4 days or until the patient's recovery. It is likely that the depletion of plasma vitamin C by repair of surgical trauma is an exaggeration of the fall in plasma ascorbic acid found to occur 24 hours after an induction.

We appreciate that several important aspects of the problem remain unanswered. It is apparent that ascorbic acid is readily released from some source under the influence of anesthesia but we can offer no explanation from our data as to how it is contained in or released by tissues. While inadequate tissue oxygenation is not responsible for the mobilization or depletion of the plasma vitamin C level it does somehow quantitatively influence the extent of these phenomena, tending to diminish both fluctuations. We have limited our discussion of the increased excretion of the vitamin with increased blood level to the con-

commitant increase in filtration rate, realizing that tubular resorption of vitamin C is very likely influenced by anesthesia also.

We can only speculate as to the cause of the exaggerated response of vitamin C deficient guinea pigs to anesthesia. Malmberg and Euler have reported that depriving guinea pigs of ascorbic acid for 3 weeks diminished the vitamin C content of the brain to $\frac{1}{3}$ of the normal value. The sensitization to anesthetization by vitamin C deficiency may or may not be but a part of a general decrease in functional capacity of all organs. We have found that an adequate supply of ascorbic acid protected guinea pigs from hepatic damage and discussed in a previous report the relation of the vitamin to hepatic function (2).

SUMMARY

During and at least for the first 7 hours following a 45 minute period of anesthesia the dog plasma ascorbic acid level increased markedly. Subsequently the plasma level fell within 24 hours to below the preinduction control levels. These observations held for cyclopropane ether vinethene and chloroform independently of the mode of anesthetization. This effect was due to the anesthetic agent and not to an inadequate oxygen intake which tended only to reduce the rate and extent of the mobilization and to decrease or abolish the 24 hour fall in plasma ascorbic acid level.

The increase and subsequent depletion of plasma vitamin C levels have been discussed

as part of a proposed concept of the overall effect of anesthesia on the distribution and excretion of the vitamin.

Vitamin C deficiency caused guinea pigs to be more quickly inducted into a state of anesthesia and more profoundly depressed by a given concentration of ether chloroform, or vinethene. The vitamin C deficient animals recovered slowly if at all from a duration of anesthesia which had little apparent after-effect on guinea pigs that had received the same scort butogenic diet but which were injected with 30 milligrams ascorbic acid daily.

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RECONSTRUCTION OF THE COMMON BILE DUCT

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IT has ever seemed to me that the greatest service a surgeon can make to the progress of the art and science of surgery is to discuss the difficulties he has met with in practice. It has been said that the chief function of an experienced surgeon is to make a difficult operation easy and in no operation is this more true than in that of cholecystectomy. Every removal of a gall bladder easy though it may seem is fraught with very great danger and one small error may convert a patient with a mild disability into one in immediate danger of death or of prolonged misery and many subsequent operations which at best may only give an incomplete life.

How great is the tragedy and misery which may arise from such errors is exemplified by the following 2 cases from my series.

CASE 45 A medical practitioner aged 58 years, after a long and useful life ministering to the sick of a busy practice and much beloved by his large circle of friends and patients was about to retire to the country to pass in peace and happiness the evening of his life, enjoying a well earned rest and pleasantly occupied with his hobbies and the visits of his friends. He was still in good health and able to enjoy an active life. He began to suffer however with flatulent dyspepsia and occasional attacks of severe pain. Believing that he had gall stones he thought to have advice before retiring and consulted a London surgeon. His diagnosis was confirmed, operation was advised and performed in 1921. The details of the operation were not available but it is known that the gall bladder was removed with one large stone. For 6 weeks after the operation there was a persistent fistula and attacks of colic. Three months later jaundice made its appearance. A second operation was performed by another London surgeon but after it there was continuous pain and frequent attacks of jaundice and rigors the jaundice later becoming persistent. When I saw him in 1924 he was thin and wasted. There was a gray green jaundice with complete absence of bile from the stools. There were frequent rigors with attacks of severe colic and the liver was enlarged and tender. The skin showed wide spread excoriations due to his constant attempts to relieve the intolerable itching. He was in profound misery and he had become a confirmed morphine addict. At operation there were widespread and dense adhesions but after prolonged dissection the portal vein and the hepatic artery were laid bare in their

whole length. No trace of a duct could be found however. An opening was made in the liver and a tube inserted but no bile escaped. He lingered on for a while taking large doses of morphine but died at the end of a year. A life which should have ended in several years of well deserved peace, happiness and comfort was converted into one of pain, misery and hopelessness.

CASE 33 In a pleasant suburb of a large south coast town there lived in 1936 a well developed, pretty and attractive girl of 21. She had been happily married for a little over a year to a young man who held a post in the shore establishment of the Navy and was certain of advancement. She had a baby son and lived in a small house in a congenial neighborhood surrounded by her friends. Having domestic help she spent her days in the enjoyment of her household duties and of her garden, rejoicing in the affection of her husband and child. Her life was one of happiness and laughter and her future seemed assured. In February of that year she had one day a sudden severe attack of pain in the upper abdomen. It soon passed off and she paid but little attention to it. It was however the small black cloud which at first no larger than the palm of a man's hand grew and grew until for 7 years it filled her whole horizon. The attacks returned and increased in frequency and severity. In April she saw her family doctor who advised operation. He operated himself, removed the appendix, and drained the gall bladder. There was no relief from the attacks of pain and in April 1937 he operated again and removed the gall bladder. It was said to contain one stone. A fistula formed and persisted for a long time and the day following the operation she became jaundiced for the first time. The jaundice continued with periodic remissions as the discharge from the fistula increased. In 1940 a provincial surgeon was called in who carried out an operation said to consist of restoration of the divided duct. It was unsuccessful and her life became one of long continued misery and pain but her spirits kept up and she continued her duties between the attacks and resolutely refused to take narcotics for relief.

In April, 1942 she was seen by a London surgeon who operated upon her in a hospital in London. Some details of this operation were obtainable. It was said that the duodenum was opened and an attempt was made to dilate the duct from below. During this procedure the duct in part tore away from the liver. She recovered from the operation but the jaundice persisted. She was told that nothing further could be done. Her condition became most miserable with constant pain, jaundice, and irritation and the depression which is so characteristic of the jaundiced state.

Fig. 1
Normal ductFig. 2
Longened ductFig. 3
Cyst duct passing to and from gallbladderFig. 4
Cyst duct passing to and from gallbladder

In April, 1933, he saw a duct whose wife I had fortunately been able to relieve of similar symptoms due to congenital cystic dilatation of the common bile duct (Case 4) and he sent her to me. I found a deeply jaundiced and unhappy patient who in spite of her miseries showed rare courage. She not only tried to joke and laugh at her troubles but still maintained the care of her personal appearance. It was the only occasion on which I was pleased to see a woman using lipstick and nail varnish. I explained to her that I might find that nothing could be done but advised operation. She willingly consented and the operation was performed at the London Hospital on April 24. There was much fibrosis but a short stump of the duct was found high up in the hilum of the liver. A long tube was inserted and the duct re-anastomosed with the jejunum. I could not say at that time in her absence instead of the long tube in the duodenum to be passed, it was turned up into the stomach and at the end of the operation removed through a small incision in that viscous. The result was most miraculous. The pain and jaundice disappeared at once. The food she ate perfectly normal color and she again became bright and cheerful but alas shortly after returning home the symptoms all recurred and it was evident that with some chills the new duct had become constricted and the tube should have been kept in until the passage was firmly established. It was one of my hardest tasks to get her to tell me that yet another operation would be necessary. She again consented, and in July I performed a successful reconstruction operation. A fistula formed for a few days but the jaundice disappeared and she was not returned. At first she had some attacks of severe pain but these decreased. In October she was free from pain and jaundice and well except for an attack of Bacillus coli pyelitis.

It is a fairly rare case the final result but if he is now cured the result is most of it. Her failing courage and faith in the power of surgery to

aid her. If I have been the fortunate medium of her cure I have the great reward of having enjoyed the complete confidence of so brave a lady.

Such tragedies although becoming only too common today are of relatively recent occurrence. According to Mowat the first reconstruction was performed by Doven in 1802 and von Stubenrauch had published the first paper proposing a fistulenterostomy in 1906. It was only after 1905 when cholecystectomy began to replace cholecystostomy that attention was widely directed to the dangers of operation. Even in 1914 the report of a case was published by Sir Alfred Pearce Gould in this case for some unexplained reason jaundice and a biliary fistula followed cholecystectomy and was cured by implanting the open cystic duct into the duodenum. It would seem evident that this was a case of an injured duct and what was thought to be the open end of the cystic duct was in reality the upper end of the divided common duct.

Since then the accident has become relatively common even in 1930 Ellisdrath was able to collect 41 reported cases and in 1937 Laker had personally operated upon 34 patients. The frequency of the lesion is due to the fact that probably in no other part of the body is there so great a variation in the anatomy. In my own work with over 1400 operations upon the biliary tract including 940 cholecystectomies the variations have been so frequent that it becomes a very difficult matter to say what is normal. In my contributions to

WALTON RECONSTRUCTION OF THE COMMON BILE DUCT



Fig. 4. Double common duct (after Eisendrath)



Fig. 5. Looped cystic duct (after Eisendrath)

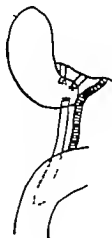


Fig. 6. Absent cystic duct.



Fig. 7. Double cystic artery

this subject I have laid stress upon these variations and have shown how easy it is to injure the common duct and the arteries. Some very valuable anatomical studies of them have been published perhaps the most important being those of Jacobson, Eliot, Eisendrath and Wilson. So far however they are not described in the usual textbooks of anatomy and since failure to recognize them is one of the common causes of injury we shall consider them in brief.

Normal relationships. The position of the various structures generally regarded as normal and as usually depicted in the textbooks is that represented in Figure 1. The gall bladder is single more or less fusiform in shape and lies well to the right of the falciform ligament. The cystic duct arises on the inner side of the lower part of the gall bladder the outer and lower pouch like portion of which is usually known as Hartmann's pouch. It passes across to join the common hepatic duct while the cystic artery runs parallel to and just deep to the cystic duct. So great is the faith of many surgeons in the constancy of these relationships that even today the positions are often regarded as certain and no steps are taken to verify them. In truth the variations are so frequent that many have come to regard the position just given as abnormal rather than normal. Abnormalities may occur in the shape and position of the gall bladder. It may even be double or absent or on the left of the falciform ligament but these conditions do not enter into our present considerations.

Variations in the ducts. Not infrequently the cystic duct is much longer than just depicted and then runs downward to join the common duct either at an acute angle or even to run parallel with it (Figs. 2 and 3). In the latter case it may be bound to the hepatic duct so that both may be divided in the belief that only the cystic duct is present. Sometimes the cystic duct is so long that it joins the hepatic duct only at the ampulla. In this case a stone may lodge in the lower part and be entirely overlooked or it may pass up the common hepatic duct (Fig. 3a) and since a probe or forceps may then pass freely into the duodenum its presence may pass unrecognized. With so long a cystic duct a considerable portion may be left behind during a cholecystectomy and if it contains a stone may dilate to form a pouch as big as the original gall bladder a condition I have described as reformation of the gall bladder. There have been two such cases in my series. According to Eisendrath there may be a double common duct or the cystic duct may form a spiral loop round the front or back of the common hepatic duct (Figs. 4 and 5). He also notes that accessory ducts may open direct from the liver into the gall bladder and this I have found on a number of occasions a possibility which demands drainage in every case of cholecystectomy. Sometimes the cystic duct is much shorter than normal and very rarely is completely absent the two hepatic ducts entering one side of the gall bladder and the common

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Fig. 9. Hartmann's pouch adherent to cystic duct.



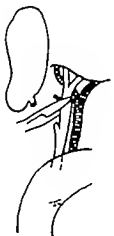
Fig. 10. Hartmann's pouch adherent to common duct.



Fig. 11. Effect of tension on gall bladder.



Fig. 12. Common duct caught in artery forceps.



but is even more likely to occur with the older method of commencing the resection of the gall bladder from the fundus for then the parts are not only more mobile but the field is obscured by blood escaping from the raw surface of the liver. I have been impressed by the fact that in so many of these cases the surgeon who performed the first operation has said to me I do not think I could have divided the common duct for the operation was so easy. It is of course in the easy case that the tissues are dangerously mobile.

Eisendrath states that in his series 12 injuries occurred in this way. If the division takes place near the cystic duct a small portion only may be removed but if the common duct is divided low down the gall bladder is pulled upon further and what is thought to be an adhesion deep in has to be cut to free it. This is the common hepatic duct which is divided right up in the hilum of the liver. It is the most disastrous of all types of injury for the upper stump may be so short that it may be very difficult to find and suture. In some cases indeed it may retract right up into the hilum and at a second operation no trace of the proximal end of the duct can be found so that the lesion is almost certain to be fatal.

Another not uncommon accident is that the cystic artery although recognized and isolated is insecurely ligatured. The ligature slips and the depth of the wound is filled with blood. The cut end of the artery retracts either under or over the common duct and the artery for

ceps with which it is caught grasps the duct (Fig. 12) and either divides it or it is included in the fresh ligature. My experience agrees with that of Lahey who states that the description of the first operation so often emphasizes the fact that it was made difficult by much bleeding. There were 3 such cases in Eisendrath's series.

CLINICAL AND PATHOLOGICAL CONSIDERATIONS

Primary obstructions of the common bile duct may of course be due to many conditions other than injury the most frequent being carcinoma either in the head of the pancreas or in the bile ducts calculus in the common duct and chronic pancreatitis. The majority of these however do not come into our present consideration. Obstructions which arise after operation as well as persistent fistulas are undoubtedly in the majority of cases due to an injury of the duct. With this opinion Mayo and Wilson among others are in accord but in a few cases the obstruction seems to be inflammatory in origin. Walters states that of 83 cases 17 were inflammatory. In such cases my own experience has been that the inflammatory change is a cholangitis perhaps associated with hepatitis and that ulceration around a stone which has been given as a common cause of benign stricture is in fact rare. Mayo states that occasionally obstruction is due to fibrosis following gall stone ulceration but if so the stone is usually in the stump of

the cystic duct. Sometimes the symptoms of obstruction appear so late after the operation that it is difficult to believe that they are due to an injury of the duct although it is quite possible that the injury was partial and was followed by a slow and progressive fibrosis ultimately causing complete stenosis. Such a sequence of events seems the more probable in that many of the operations performed for the relief of an injury have been immediately successful, but the symptoms have returned sometimes after a long interval and these relapses often appear to be due to progressive fibrosis. As far back as 1914 Mann reported a case in which obstructive symptoms commenced 5 months after cholecystectomy but an operation was required only at the end of 2 years. Wilson reported another in which obstruction only occurred 7 years after the operation and he quotes Judd as putting forward the view that these late obstructions are due to an obliterative cholangitis. Apart from these doubtful cases there are others in which it is definitely due to some cause other than injury at the first operation. The most important group are those due to the failure on the part of the surgeon to appreciate the nature of the pathological condition which consists of a double lesion. There may be gall stones associated with chronic pancreatitis or with carcinoma of the head of the pancreas. If the gall stones alone are recognized and the gall bladder is removed obstructive jaundice will follow or if the common duct is drained there will be a persistent fistula. This is perhaps more likely to occur if the obstruction has led to hepatic failure with the presence of white bile for the colorless fluid in the gall bladder may be regarded as the mucoid secretion behind an obstructed cystic duct. A similar error may be made with multiple carcinomas, one growth being low in the common duct and another in the cystic duct. Such errors would have been avoided if the surgeon had observed that the common duct was dilated or preferably had made sure that there was a free passage to the duodenum.

In this communication I am considering a series of 46 cases. The first group of 33 includes the injuries and 5 cases of congenital cystic dilatation of the common duct for the ma-

jority of the latter presented as cases of jaundice following operation. The second group consists of 1 inflammatory stricture, 4 cases of chronic pancreatitis and 8 out of my 49 cases of carcinoma of the common bile duct for they were all treated by reconstruction of the common bile duct.

Two syndromes may occur after an injury which has not been recognized at the time of operation. In the one the duct has been divided and after operation all the bile drains through the tube. The fistula persists, the stools become white and it is manifest that there is external loss of all the bile. For a varying time the patient may remain in relatively good health but ultimately and sometimes rapidly goes downhill as a result of the complete loss of bile. In some of the reported cases attempts have been made to reintroduce the bile into the stomach either as a drink, usually unsuccessfully disguised or through a stomach tube. In the other group of cases in which the duct has been tied or has gradually stenosed, there is the immediate or slow onset of obstructive jaundice, the color of the patient slowly changing from bright orange through dull green to gray until in the end he comes to look more like a half-caste than a jaundiced patient. Throughout the stools are clay colored and contain no trace of bile. The skin shows excoriations from the intolerable itching. There is rapid loss of weight and soon the onset of an extreme mental irritability. The liver function falls so that at a later operation the dilated upper duct contains a thin white fluid like water with often no trace of bile. As a rule the deterioration is much more rapid than in the first variety but some unfortunate sufferers become confirmed morphine addicts, for severe colic-like pain may occur with the obstruction, and may survive even for several years (see Case 45). At a second operation the first type is generally the better operative risk but the upper end of the duct is small and surgical manipulations are difficult. In the second type the proximal duct is dilated and therefore the operation is easier but the patient is a much worse risk. In some patients the symptoms are combined. There may be a fistula but the duct is narrowed so that obstructive jaundice is also present. Many

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of the patients have had several operations in an attempt to overcome their disabilities

At operation the field is greatly obstructed by dense adhesions the omentum the colon and the stomach being firmly united to the abdominal wall and the duodenum omentum or stomach being densely adherent to the original bed of the gall bladder There is no type of operation which more clearly exemplifies the rule that no attention whatever must be paid to the pathological condition until the anatomy has been restored By gentle dissection with the edge of the knife used more like a paint brush, at the line of junction all these adhesions can be gradually separated by a completely bloodless procedure The structures are gradually recognized and retracted until the region of the edge of the gastrohepatic omentum is reached with the liver above and the duodenum below Somewhere in the mass is the divided duct Usually its distended upper end or the opening of the fistula may be seen The former may be difficult to distinguish from the portal vein In such cases much time may be saved by aspirating the doubtful swelling with a fine hypodermic needle as first advised by Balfour In nearly all my own cases the lower end of the duct could be discovered only with great difficulty or could not be found at all Mann and Jackson appear to have had a similar experience In the worst type of case often where there have been two or three previous attempts at repair the hepatic artery and portal vein may be exposed in their whole length and no trace of the duct can be found A hypodermic needle should then be inserted into the hilum and in fortunate cases may strike the dilated duct up in the substance of the liver All these operations are prolonged and difficult, the patients are had risks and the mortality is of necessity high

OVERLOOKED AND FATAL CASES

It is probable that there have been a considerable number of cases in which an opening has been made into the common duct it has not been noticed there has been a free escape of bile into the peritoneal cavity and the patient dies within a few days No postmortem may be held but in any case no report is made

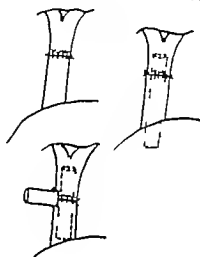


Fig. 13 Methods of end-to-end suture

The frequency of such an accident is impossible to determine However it was the occurrence of an accident of this sort in my practice more than 30 years ago which first directed my attention to injury of the common duct I operated upon a woman of 52 performing cholecystectomy for acute cholecystitis She rapidly developed peritonitis and on the 4th day a pelvic drain was inserted and hile and pus escaped. She died next day At the post mortem 1 inch of the common duct was found to be missing Fortunately the specimen has been kept and the missing piece of common duct was found attached to the cystic duct. It taught me a most valuable lesson but unfortunately gained at the expense of a life I am pleased to say that I have never accidentally injured a common duct since and hope that what knowledge I have gained on the subject may save others from a like experience

METHODS OF REPAIR

End-to-end suture As a rule end-to-end suture is applicable only at the time of the first operation when there is no fibrosis and the lower end of the duct has not become shrunken. It can therefore be used if the injury is recognized at once In some cases a direct suture is used in others the repair is made around a rubber tube passed either down to the ampulla or through into the duodenum. Recently the use of a vitallium tube has been advised by Pearce (Fig 13) Mayo advises end-to-end suture around a T tube wherever possible It is also advocated by Elliott Ginsburg and Speese and

Eisendrath. It may also sometimes be used where there is a small localized stricture either fibrous or carcinomatous which can be excised and yet leave enough healthy duct above and below for easy approximation. In my own series end-to-end union was possible in only 3 cases. In the case of congenital absence of the cystic duct, union was accomplished over two tubes inserted into the hepatic ducts. In 2 cases fibrous strictures, one of which was probably due to injury were excised and simple end-to-end suture without tube was performed. The one following injury died 3 days after operation. These operations like every other method are always difficult. Even with an immediate union the duct may be small and deeply situated so that much time is consumed and the patient's reserves are strained. Of the patients who recover the end results are not always satisfactory. In my own case of absent cystic duct, the patient made a good immediate recovery but after 3 years had recurrent attacks of pain, rigors and jaundice. Further operation was refused, she gradually developed enlargement of the liver and spleen and 11 years after operation died from a severe hematemia due to portal obstruction. Elliot and Eisendrath report similar recurrences. The third patient made a good recovery and was well at the end of 3 years.

Dilatation of the stricture. It is only in a few cases that such a form of treatment is possible and it is but seldom that it is likely to be successful. Of the few cases reported in the literature it is only noted as having been attempted previous to some more radical step being undertaken. It will be noted that in 3 of my own cases a second or third operation had been unsuccessfully performed to dilate the stricture before they came to me. In 2 of my own cases in which there was only a slight narrowing following a previous operation, dilatation alone was attempted both had recurrent attacks which were slight, however and the patients were able to lead a normal life.

Local plastic operations. In certain cases local operations have been performed on the narrowed part of the duct. In most cases these have consisted of a longitudinal incision of the narrowed area which is then sutured transversely either by direct suture or around

a tube. It is not likely to be successful unless the stricture is very narrow. Elliot states that it is only likely to be temporary and Walters reports 3 cases in which the results were only fair there being attacks of incomplete obstruction since the operation. Lahey has reported 3 cases sutured around a T tube, in all of which good progress was made and patients were well, respectively 9, 10 and 14 months later. In 2 of my cases (17 and 32) this operation had been previously attempted in 1 case with no and in the other with only temporary relief. It is a method I have never used.

Cholechochooduodenostomy. This is a long accepted and perhaps the oldest method of overcoming an irreparable obstruction of the lower part of the common bile duct where the gall bladder either because of its previous removal, or because of its diseased state, is not available for the performance of a cholecyst gastrostomy or duodenostomy. It was apparently first performed by Reidel in 1881 but the patient died of biliary leakage. The first successful case appears to be that of Sprengel in 1891. Later cases were reported by Swain and Fullerton, in some of which the anastomosis was carried out with a Murphy button but Rowlands advocated the use of a simple suture in 1907. It soon became popular and Sasse even advocated its use in cases of obstruction by a calculus. Hors performed the anastomosis around a rubber tube which was brought out through a second opening in the duodenum lower down and was drained externally. It is an unsatisfactory method however in the class of case under consideration because the ordinary method of lateral anastomosis necessitates a dilated duct in close approximation to the duodenum, and it is therefore usually replaced by one of the methods of direct or indirect implantation. Walters states that the best results follow cholechochooduodenostomy or hepaticoduodenostomy but it is not clear whether he means a lateral or a terminal anastomosis. In my own 5 cases of congenital cystic dilatation of the common duct which often closely resembled cases of injury in that colic and jaundice followed a previous operation, sometimes even a cholecystectomy it was the method of choice. I have also used it in a large number of cases

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Fig 14. Fistuloenterostomy



Fig 15. Direct implantation (Mia-yo method)

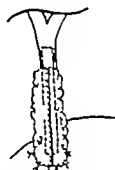


Fig 16. Oshien reconstruction around tube (Sullivan method)

of carcinoma of the lower duct and head of the pancreas and in cases of chronic pancreatitis but I have never considered it as suitable for the treatment of cases of injury

The use of autogenous grafts If there is a long gap between the cut or dilated end of the duct and the duodenum it is perhaps natural to consider the transplantation of a free graft to bridge the deficiency. In 1913 Molineux advocated the use of the appendix for this purpose and in 1914 Giordano and Strope used portions of a vein. Davis and Lewis in 1913 experimentally used strips of fascia. It never seems to have become a popular method although Ginsburg and Speese reported a case successful after 2 operations in which a portion of new duct was made from a strip of posterior rectus sheath. I have never used it as it seemed to me that a free graft deprived of its blood supply would be very prone to necrose and its use therefore be followed by an immediate fistula or by a later obstruction

Fistuloenterostomy In 1906 von Stubenrauch proposed that the external end of a permanent biliary fistula should be dissected free and anastomosed with the intestinal tract (Fig 14). It was apparently first performed by Sutton in 1910 but without success a fecal fistula following. According to Walters the first successful operation was accomplished by Williams of Boston in 1914 the patient being alive and well in 1929. Just as with a pancreatic fistula it is an attractive measure for a portion of the fistula can easily be dissected out with very little disturbance to the patient the prolonged dissection to lay bare the duct being avoided. Walters advocates its use and

reports 4 cases of his own and quotes cases by St. John and Lienthal. Lahey has also reported 2 successful cases. Theoretically however there are objections to its use. It is a common experience to find that long continued fistulas tend to close for a time the patient then becomes jaundiced and later the fistula breaks down again. If this happened after the anastomosis the condition would be as bad as before. There are also the dangers that the fistula may necrose and since the opening is not valvular that sepsis may ascend from the intestine and cause cholangitis. Hoag believes that these objections are not only theoretical for he says that although at least a dozen successful cases have been reported there have been more failures than successes. Lahey also finds it unsatisfactory stating that of 14 cases only 2 had permanent relief. Wilson also brings forward strong arguments against its use. He quotes Elliot as having collected 41 cases of which 22 were united to the duodenum 18 to the stomach and 1 to the jejunum. There were 18 deaths and 9 developed strictures one a second time. Most of the failures were due to contraction of the tract. I have not used it nor had it been previously attempted in any of my cases. If no duct can be found the only hope is to form a fistulous tract from a puncture in the liver and later anastomose it to the intestinal tract

Direct implantation The direct anastomosis of the cut or obstructed end of the duct to the intestinal tract would seem to be the natural method but a simple anastomosis would have the theoretical objection that there would be no valve and ascending sepsis with cholangitis

would be likely to occur. The first operation seems to have been performed by W. J. Mayo in 1905 but with his customary genius he made the opening into the duodenum semi-lunar in shape so that a valve was formed (Fig 15) the patient being alive and well after 15 years. It has since remained the most popular of all methods and should be employed where possible. Balfour states that in over a hundred cases it is the best method and that in no case was there evidence of subsequent obstruction. Walters, however in a later communication says that of 6 cases the results were very good in 5 but 1 developed cholangitis. Many surgeons support its use though several have modified it, especially by the use of a tube in forming the anastomosis. The case previously quoted of Sir Alfred Pearce Gould and reported in 1914 was treated by simple anastomosis with apparent cure. Packard and in 1908 and Harrington in 1909 reported successful cases treated by the Mayo technique. Mann used a tube sutured into the duct and then invaginated into the duodenum after the manner of a Senn Kader gastrotomy. Jacobson employed a similar method but used a loop of jejunum brought up in front of the colon as the duodenum was not mobile. The end of the duct should preferably be implanted into the duodenum but if the latter is too fixed or does not appear to be healthy the stomach or a loop of jejunum may be used but as Wiedemann pointed out the colon should never be utilized as the risk of ascending infection is increased. If a tube be used Wilson advocates that it should not pass far into the duodenum or it may come away too quickly. McArthur on the other hand, advises it as it will pass more easily. This question will be discussed more fully later. In my own series there were 6 cases all due to previous injury. In each case the divided end was implanted into a crescentic opening in the duodenum by the Mayo method. In 4 cases in which the duct was not greatly dilated a tube was used and made to project well into the duodenum. In 2 a simple anastomosis was performed. Two of the patients did not survive operation. In 1 of these the duct was greatly dilated with white bile. There is no doubt that this is an evidence of hepatic failure and the patient is a bad operative risk, the sudden lowering of pressure within the duct being of considerable danger. In such cases Ravdin and Frazier have made the valuable suggestion that as a first stage a tube should be fixed into the stump of the duct brought out through the wound clamped and the liver slowly decompressed the anastomosis being completed at a second operation. Of the 4 cases that survived 1 died 8 years later with cholangitis 2 were alive 2 and 3 years later but 1 was having some attacks of pain and jaundice. The last case has been watched only 7 months. His was a bad case, he had had 3 previous operations. He has had some attacks since operation but they are getting less.

Reconstruction of the common bile duct. In many cases there is so much dense fibrosis and the proximal end of the duct is so short that direct implantation into the duodenum is difficult or impossible. A loop of jejunum might be drawn up but at such a height there is a risk that it might become angulated and therefore some form of indirect implantation or reconstruction of the duct is often preferable. Many different methods have been used but in nearly all the new duct is formed around a rubber tube. According to Mount this was first carried out by Doven in 1892 but the patent lacy. Interest was first generally stimulated by the work of Sullivan who in 1909 operated on dogs bridging a gap in the duct with a rubber tube. Around the tube omentum was wrapped and sutured in place (Fig 16) and when the tube was passed this formed the new duct. Soon after Brewer reported 2 cases 1 died soon after apparently from obstruction. Brandt also reported 5 successful cases, but Wilms found that in his first 3 cases the tubes gave rise to much trouble by escaping into the peritoneal cavity. Two of the 3 tubes which replaced the first ones were vomited. Hager in 1918 reporting a case of his own in which patient died 7 months later with cholangitis, states that up to that time 22 cases repaired by Sullivan's method had been reported. Theoretically the method suffers from the drawback that leakage is likely to occur round the flap which will then be prone to give way.

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Even if this does not occur the new tube is not lined by epithelium and is thus at best only a fistula which will tend to contract. The opening into the duodenum is in no way valvular and thus ascending cholangitis would be probable. In support of these objections Wilson says that of 38 collected cases there was a mortality of 39 per cent and that recurrences were common with cholangitis abscesses of the liver and biliary and duodenal fistulas.

A consideration of these difficulties led me to devise the operation published in 1915 where by a new duct having a valvular opening was fashioned from a flap of duodenum sutured around a tube. This method can be used as a terminal reconstruction when the duct is completely divided or as a lateral reconstruction through a side opening made into the dilated duct. This was suitable for some cases of carcinoma extending far up the duct.

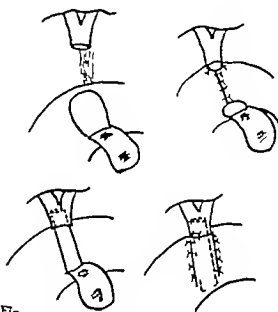


Fig. 17 Reconstruction by duodenal flap

The steps of the operation are as follows: By careful dissection the upper end of the duct is freed and opened if necessary. The duodenum is drawn up and sutured to the posterior edge of the duct. A wide flap is then cut from the whole thickness of the anterior wall of the duodenum and turned downward. The upper end of the resulting opening in the duodenum is closed with a few stitches. A piece of rubber tube of as large diameter as possible is inserted into the duct and sutured in position with catgut. The lower end is passed into the lower part of the duodenal opening. The duodenal flap is then turned up and sutured round the tube to the duodenum and to the anterior margin of the cut duct (Fig. 17). Schragar and Ifoag both have devised methods of making a new duct out of a tube of gastric mucous membrane but in neither case is the opening valvular. Ginsburg advocated a modification of my method where by the flap was turned up instead of down and R. P. Sullivan reported a case he had treated by this method using a T tube. Seven months later there was a recurrence. I tried this modification in 2 cases but found it more difficult and it has the drawback that the opening is not valvular. In my own series there have been 16 cases of terminal reconstruction: 1 for fistula following cholecystectomy and obstruction from chronic pancreatitis, one after excision of car-

cinoma of the duct and 14 for injury. The patient with chronic pancreatitis made an immediate recovery, was able to fight in Gallipoli in the last war and was free of all symptoms when last heard of 15 years after operation. The patient with carcinoma did not survive the operation. The 14 cases of repair after injury were all difficult. Several had had a second or even a third operation. The operative field was obliterated by dense adhesions which required prolonged and careful dissection to restore the anatomy. The remaining portion of the duct was of varying length sometimes being high up in the hilum at other times being an inch or more in length. Contrary to Mayo's observations often no trace of the lower end of the duct could be found. On many occasions Balfour's device of proving a doubtful stump by aspirating through a hypodermic needle was of great value and saved much prolonged dissection. The majority of the patients were bad risks and especially was this the case when the duct was filled with white usually dying with evidence of hepatic insufficiency. 4 are quite well and have remained so after intervals of 10, 6, 2 years and 4 months respectively. Two have since died of other conditions: 1 of meningitis 3½ years later and the other of carcinoma of the colon 7 years later. Three died 3, 2 and 1 year later with cholangitis and had a recurrence.

SURGERY GYNECOLOGY AND OBSTETRICS

There were 11 cases of lateral reconstruction 3 from obstruction from chronic pancreatitis 7 with carcinoma of the duct and pancreas in whom a simple choledochoduodenostomy did not seem suitable, and 1 with a fibrous stricture. Of the 3 with chronic pancreatitis 2 did not survive the other was in perfect health 6 years later. Of the 7 cases of carcinoma 3 did not survive but the others gained considerable relief up to periods of 1 year. The patient with fibrous stricture although 76 years old at the time of operation was in perfect health and leading an active life traveling at the end of 5 years.

Hepaticoduodenostomy There are certain cases probably those in which the duct was divided after traction upon it so that the upper division was at the hilum, in which no trace of a duct can be found. The cut upper end may have retracted up into the liver and be entirely lost. Even in such cases a hypodermic needle should always be inserted in the hope that the stump of a dilated duct is just beneath the surface. If none can be found the condition is almost hopeless although attempts have been made to establish an anastomosis between the ducts in the liver and the intestinal tract.

Elliot has collected several cases of this type the first being that of Garré in 1908 and another of Doberer in 1910 both of which he says were successful. In 1936 he had collected 11 cases all German. In these cases the liver was punctured with a cautery and drained. If a biliary fistula is formed it is later anastomosed to the duodenum or jejunum but as Wilson points out the drainage can be only partial so that a biliary fistula may not relieve the jaundice and strictures of the fistula are likely to follow. In 1912 Lameris cut the free edge of the liver and sutured it to the intestine. Infection spread to the ducts, and the patient died 8 months later. There were 10 of my own cases in which no duct could be found as also in 1 case of congenital obliteration of the bile ducts a puncture was made and a tube was sutured into it. In 1 there was a very slight escape of bile for 2 months which then ceased. In the 2 others no bile at all escaped and the patients although still alive

for 9 and 10 months respectively after operation were living in profound misery and steadily going downhill.

The use of rubber tubes It will have been noticed that in many of the operations tubes generally of rubber have been used. In immediate end to-end unions their function has been mainly that of an internal splint to facilitate the introduction of the suture. In this case generally speaking the smaller the duct the more useful the tube the larger ducts being more suitable for direct suture or implantation. In old standing cases with much fibrosis or absence of a portion of the duct, there has been more uncertainty as to their value. If a tube is used it may as mentioned in cases of Sullivan's operation escape into the peritoneal cavity and Wilson states also that it may be displaced upward or may become kinked. Many surgeons have feared that being a foreign body it would if long retained set up a cholangitis or would become encrusted with bile salts and its lumen thereby be occluded. In one of my cases (Case 28) the tube was retained for 6 months and did so become occluded but in all other cases it was passed much earlier.

In many of the cases which are reported it is stated that the tube has not been noted to have been passed but apparently no trouble arose. Today if there is any doubt, its presence would be determined by the x ray. On the other hand if no tube be used any gap which is not lined by mucosa is almost certain to contract and even if a mucosal lining be obtained throughout dense external fibrosis may cause much constriction ultimately progressing to complete obstruction and it would seem to be necessary to retain a tube until the new passage is established. There is, however, a difference of opinion as to the time required for this. Wilson says that a tube should not be in place for a long while. McArthur states that if a long tube be used reaching down into the duodenum it will pass easily and evidently regards this as desirable. Many surgeons have attempted to overcome this difficulty by using T tubes which can be left *in situ* for a long time and withdrawn when it is thought that the new passage is established. In 2 of Lameris

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REFERENCES

- cases it was left in for 4 months and in R P Sullivan's case for 6 months. There are how ever grave theoretical drawbacks to the use of T tubes. Their withdrawal is very prone to injure the duct and for this reason I never employ them in biliary surgery. The formation of a lateral opening is also very undesirable as it may originate a biliary fistula. Recognizing these difficulties Eisendrath and Hürz both devised operations in which the tube was passed down the duodenum brought out lower down and drained externally. It could be withdrawn when desired. In my reconstruction method the tube always passes into the duodenum and has been extruded spontaneously in all but the case mentioned above in periods varying from 10 to 42 days. In Case 30 it was brought out through the stomach in the manner of a gastrostomy tube and removed in 2 weeks but the patient died in 2 years with cholangitis and in Case 33 it was merely used as a splint and removed through the stomach at the end of the operation. Obstruction recurred in 3 weeks. In the future I shall always leave the tube projecting into the duodenum in he passed naturally for I believe it should remain in place for several weeks. If obstruction should recur while the tube is still in place as confirmed by the roentgenograms then it could be removed through a small incision made in the duodenum.
 - The subject of surgery is very vast and I have only opened for discussion one very small section which might well have been entitled 'How to remove the gall bladder. An equally wide discussion might be devoted to the question of When to remove the gall bladder. The conclusions I have put before you are based on 30 years of major abdominal surgery. Hippocrates has said that experience is fallacious and judgment is difficult but if as the result of my experience I have been able to impress upon you and especially upon the younger members among you one great principle of surgery that no structure in the human body must ever be divided until it and its immediate surroundings have been clearly displayed then my 30 years work has not been wasted.
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HOMANS QUIET VENOUS THROMBOSIS IN LOWER LIMBS

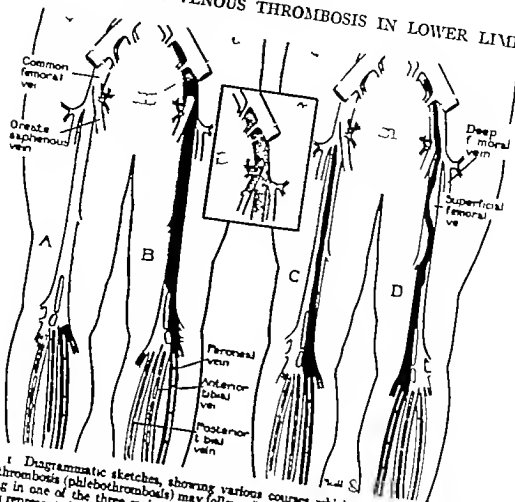


Fig 1 Diagrammatic sketches, showing various courses which a deep, lower leg quiet thrombosis (phlebothrombosis) may follow. In each case, the disease is shown as starting in one of the three main venous systems of the calf. A, The quiet thrombosis is represented as having failed to progress above the popliteal region. There is no propagating mass in the popliteal or femoral vein. B The quiet thrombosis has progressed into the femoral vein where it now fully obstructs the femoral and external iliac and hypogastric veins—a present day conception of femoroliliac thrombosis or phlegmasia alba dolens. No attempt is made to indicate the inflammatory reaction about the great vessels or the involvement of collateral channels. (The insert represents an older conception of femoroliliac thrombophlebitis, starting in the region of the groin and spreading distally for an indefinite distance into the superficial femoral vein.) C The thrombosis has formed a propagating floating mass, not adherent to or obstructing the femoral vein. At this stage a fatal pulmonary embolism is seriously threatened. D The thrombosis has reached a fairly advanced stage, being adherent to without obstructing the femoral vein and having extended through the left external into the common iliac vein. At this stage, emboli of fair size may readily be detached.

The accompanying diagrammatic sketches will give some idea of these various courses which can briefly be described as follows

- 1 The initial thrombosis in the lower leg develops into a thrombophlebitis and causes the typical swelling of phlegmasia alba dolens (Fig 1 B)
- 2 The initial thrombosis remains confined to the veins of the lower leg in which it originates and there heals (Fig 1 A)
- 3 The initial thrombosis propagates through the popliteal into the femoral vein and forms a

soft floating mass capable of causing pulmonary embolism on a large or small scale (Fig 1 C)

- 4 The initial thrombosis propagates through the popliteal into the femoral vein where it becomes more or less adherent without causing obstruction and may come to occupy most of the femoral and external iliac, advancing at times into the common iliac vein and even into the vena cava (Figs 1 D and 2 B)

It is proposed to deal in detail with the non obstructive embolus-threatening processes

but before doing so to describe briefly the obstructive femorotiliac thrombophlebitis, explaining why this form does not seem to require surgical intervention and recounting the sorts of treatment which seem most acceptable today.

Femorotiliac thrombosis—its source and treatment. There are at least three good reasons for believing that this process usually arises from deep quiet lower leg thrombosis. First Bauer (3, 4) has traced by venographic studies the development of the full fledged obstructive phlegmasia alba dolens from its source in the deep veins below the knee. Second one can sometimes secure a history of pulmonary infarction indicating that a soft, nonobstructive thrombosis has preceded by some weeks the appearance of the typical edema and discomfort of a femorotiliac thrombophlebitis. And third there are observations such as are related by Conner in experiences with typhoid fever of very suggestive early signs in the form of pain and tenderness in the toes, feet and calves before the unmistakable swelling of "phlebitis" becomes apparent. Bauer (4) and others have estimated that 90 per cent of femorotiliac thrombophlebitis is of such origin and that only 10 per cent perhaps commences in the groin or pelvis. The exact ratio between the two varieties is really not important. It is enough to realize that in the light of today's knowledge only recognition and operative treatment of its early pre-obstructive stage can prevent the full development of the disease.

The essential difference between phlegmasia alba dolens and an advanced quiet thrombosis (phlebothrombosis) lies in the as yet unexplained inflammatory reaction about the great artery and vein in the femoral and iliac regions. For only when the venous stream is fully obstructed by a solid thrombus does this reaction set in giving rise to the edematous limb enlarged from toes to groin often painful and usually marked by tenderness over the femoral vessels together with some perivascular inflammatory thickening at the groin. The reaction may be minimal or may take the form of an acute nonsuppurative exudate involving the nearby nervous and lymphatic structures quite as much about the artery (11) as the (15)

vein. It certainly offers an explanation of the occasional vicious local spasmodic constriction of the artery and of the irritating impulses which appear to travel centrally from the region involved calling forth reflexly, by way of the sympathetic system the peripheral vasoconstrictions which are recognized today as a major cause¹ of the edema and discomfort in phlegmasia alba dolens.

The treatment of thrombophlebitis is directed toward releasing the generalized vasoconstriction by making a sympathetic block with procaine—repeatedly if necessary as Leriche and Kunlin (16) and Ochsner and DeBakey (18) have pointed out. The matter is brought up here only to indicate that the prevention of embolism is not a problem. In deed there is a very good general rule almost a law that the greater the swelling and discomfort the less the danger that a soft, detachable mass exists. And if in the presence of phlegmasia alba dolens embolism actually occurs one can be reasonably certain that it comes, not from the vein of the swollen limb but from the other or innocent appearing leg. In all probability exploration and division of an inflamed fully obstructed vein with extraction of such of its adherent thrombus as can be sucked out will relax the associated vascular constrictions but this is substituting a rather considerable operation for a lumbar sympathetic block. Nor is it clear at what level such a division should if at all be performed. If an operation is undertaken its advantages and disadvantages should be understood much more fully than is at present the case. And whether or not sympathetic procaine block is used the swollen leg of thrombophlebitis should be drained of its fluid by elevating the foot of the patient's bed and by allowing such motion in bed as can comfortably be made. As fever disappears and the swelling recedes, exercise of the dependent leg should gradually be instituted. Bandaging from toes to knee is necessary at

¹One should recognize that venous obstruction is, by itself, no empty or silent cause for edema, as Leriche and DeBakey here shows experimentally. And the sympathetic, if involved in the inflammatory reaction, or even perhaps if they are not, may be unable to carry off the large quantity of irregularly pronounced venous fluid due to venous obstructions. In any one instance, one can only guess at the relative importance of these various factors, but, supposedly, the greater the discomfort (or pain) edema and generalized cyanosis (without obvious engorgement of the veins) the more likely is reflex vasoconstriction of the arteries and vessels to be the principal factor responsible for edema.

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this time when the venous blood is finding new channels of egress from the limb. Edwards and Edwards have pointed out that even though canalization of the principal vein subsequently occurs the valves of the thrombosed vessel are necessarily ruined making it functionally useless.

HEALING OF THE INITIAL THROMBOSIS WITHOUT EXTENSION OR EMBOLISM

How often this takes place in the absence of operative treatment or indeed of any treatment at all is impossible to say. Very little help is to be obtained from statistics. In a recent study based on adequate diagnostic criteria Welch and Faxon (22) in 1941 find that the ratio of fatal embolism to recognizable phlebitis in 250 cases at the Massachusetts General Hospital during the period 1935-1939 was 1 in 25 and that 1 patient in 3 with phlebitis suffered an infarct. Such figures relate however to all stages of thrombosis early and late and entirely to hospital experience which appears to vary from institution to institution. Most surgeons hold that neither healing nor freedom from embolism can be predicted and that once a diagnosis of deep venous thrombosis in one or both legs is reasonably certain whether the chances against a fatal embolism are 15 to 1, 25 to 1, or even higher they are not justified in withholding a safe easily performed interruption of the femoral vein. They expect in fact to operate on many patients in order to save the life of one—a perfectly justifiable attitude. Actually as will presently appear there is no way of telling whether a deep lower leg thrombosis has ceased to extend or is forming a soft propagating thrombus which will wave in without in the least obstructing the femoral vein (Fig. 1 C).

The clinical evidence of a deep quiet venous thrombosis in the calf is obviously quite different in ambulatory persons and in those already confined to bed. No age beyond in

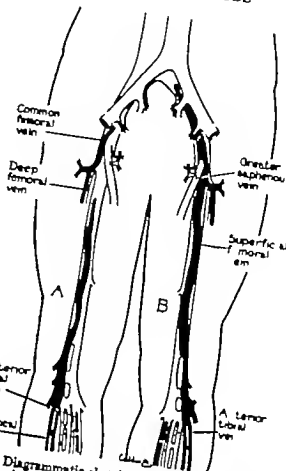


Fig. 2 Diagrammatic sketches of advanced stages of a quiet lower-leg thrombosis. A, A propagating thrombus has advanced into the upper right femoral vein and at the same time an independent thrombus has started in the deep femoral (profunda femoris) propagating into the common femoral vein. Section of the superficial femoral vein would neither reveal or control this second process. B, A propagating thrombus has become adherent to, without obstructing the left femoral vein and has advanced into the common iliac vein. Its proximal end may easily be detached. An associated thrombosis is present in the deep femoral system.

fancy is free from the accident of thrombosis though it is most common in the 6th decade and beyond. When attacked in active life the individual may notice some degree of lameness of the calf in walking, some little edema of the ankle occasionally only such vague symptoms as hardly to trouble a busy person. There may have been a minor accident or unaccustomed strain. Any lameness and swelling which are present will be relieved by a few days rest in bed but will recur on renewed use of the limb.

When thrombosis occurs during posttraumatic, postoperative or postpartum life in bed or in the course of any serious illness there may be even less to call attention to the local

The interesting statistics of Barker, Nygaard, Walters and Priestley (23-1941) give no information as to this question, since the criteria for diagnosis of deep lower leg thrombosis are not stated. However they make the important point that even an embolism has occurred the chance that fatal embolism will follow is approximately 1 in 3. They show how unsatisfactory the diagnosis of venous thrombosis had been during the decade previous to 1910, in only 31 per cent of all cases of pulmonary embolism occurring. A year prior to the 31 to Clark was clinical or pathological diagnosis of thrombophlebitis made. These figures relate solely to postoperative experience.

disease. It is under these circumstances that embolism is so apt to come out of a clear sky. However, there is often pain in the calf ranging from mere soreness to a real ache. There may or may not be some swelling of the ankle and lower leg. There may be tenderness of some of the toes, of the foot or of the calf. More especially, there may be some sign of irritability of the great posterior calf muscles. This can be brought out by strongly dorsiflexing the foot—dorsiflexion sign. The muscles may merely resist passive dorsiflexion which will be less complete than upon the opposite side, or there may be discomfort, referred to the back of the calf or the popliteal space. The muscles, to the grasp of the fingers, will often feel full and a little tense. Finally, if the individual can sit or stand up, the foot of the dependent leg will perhaps appear faintly cyanotic, again as compared with the opposite side. It may be necessary to leave the legs dependent for several minutes to bring out this sign.

If conservative treatment is elected, the idea behind it is that thrombosis will usually cease to progress when and where it meets the active current of another vein. There is an opportunity for this favorable event in the coming together of the several systems of veins of the lower leg in the popliteal region. One should expect it most often in the young and vigorous and least often in the elderly and feeble. The patient should be allowed freedom of movement in a bed of which the foot is elevated from 4 to 6 inches. Ten days will usually see all signs of thrombosis disappear. Then the leg is exercised actively at first in elevation and finally then bandaged in actual walking. Such treatment has previously been described. Originally the writer's (12, 13) attitude was that only if, after a fair trial of conservative measures, the signs and symptoms of thrombosis recurred, should femoral section be urged. However, since experience has shown that nonoperative treatment is more often followed by recurrence than by a permanent cure, and since embolism is always a threat, an early femoral interruption should prevail over conservatism. The level of section or ligation, in the absence of any signs of a propagating thrombus in the femoral, should

be the superficial femoral vein at the groin just below the great branch entering from the thigh (profunda femoris). This procedure will briefly be reviewed under the next heading that is, thrombosis in the lower leg complicated by a propagating thrombus in the femoral vein.

THE PROPAGATION OF A DEEP THROMBOSIS IN THE CALF INTO THE FEMORAL VEIN IN THE FORM OF A NONOBSTRUCTIVE NONADHERENT THROMBUS

This is the state with which surgery chiefly deals. It represents an early stage of the progress of thrombosis into the femoral vein, the dangerous stage before the thrombus becomes in any degree adherent. It is the source of the long pulmonary embolus which kills so quickly. However, a small fragment of the propagating mass often breaks off—a preliminary shot as it were—causing signs of moderate pulmonary embolism in the form of substernal pain, pleuritic pain or even merely cough, faintness or breathlessness. Perhaps, least often, the embolism excites the classic pain in the side associated with hemoptysis. Reference to pulmonary embolism is made here to indicate that it offers the most certain evidence of the presence of a loose propagating thrombus. Without it, one can only make a diagnosis, by the signs described under the previous heading, of a quiet deep thrombus below the knee. For the unattached propagating mass adds nothing to the local picture produced by that condition.

In this connection Allen Linton and Donaldson (1943) make the following statement, based on their most recent experiences at the Massachusetts General Hospital:

During 1942 many vein interruptions were undertaken upon patients with symptoms localized to the lower leg, and in this group thrombosis of the femoral vein is not expected. Our present opinion is that, if possible, the operation should be carried out before thrombosis has extended into the femoral and iliac veins. As our diagnosticumen improves in detecting early thrombosis, the number of negative explorations will increase, yet the protection afforded by the operation is not diminished.

Their table of diagnostic signs indicates that 81 per cent of their patients showed something significant on their chart. 67 per cent

showed some degree of swelling of the limb 61 per cent showed some evidence of tenderness and in 41 per cent the initial symptom was some sort of thoracic pain. They stress the advantage of noting on the chart an elevation of temperature pulse and respiration and they deprecate the value of what DeBakey and Schroeder and Ochsner have properly insisted on calling phlebography rather than venography. They find contrary to the views of these writers and to the earlier conclusions of Welch Faxon, and McGahey (23) that positive clinical evidence of thrombosis with a negative phlebogram has been secured in one third of their cases studied. And they believe that since the ideal time to section the femoral vein is when thrombosis is still localized in the lower leg it is in early cases when phlebography is most difficult to interpret that a positive result obtained by this means is most desirable. In fact they take issue with those who advocate phlebography as a prime factor in the early diagnosis of phlebothrombosis.

The operative treatment of a deep lower leg thrombosis whether a loose propagating thrombus is merely suspected of being or is known to be present, consists in exploration and division of the femoral vein at the groin. Ordinarily in the early case the superficial femoral vein below the entrance of the profunda, is exposed isolated between guy ligatures or rubber tubes and opened. The direction of the incision is not vital though a long cut parallel to and about 2 centimeters below the inguinal ligament is perhaps most satisfactory. For by this route the great saphenous vein, which is the quickest guide to the femoral vein, is most easily found. The femoral vein itself lies mesial to the artery often almost directly behind it. The profunda enters some what distal to the saphenous as is shown in the various diagrammatic sketches.

As a rule either no thrombus is seen in the vein or a nonadherent floating mass is encountered. In the former case the vein is merely sectioned between double ligatures in favor a backward flow of blood and the soft clot is sucked out through the smooth glass tube. Then the vein is doubly ligated above and below the opening and divided. The cir-

cumstances under which the common femoral proximal to the deep femoral (profunda femoris) should be closed will presently be discussed. Under the conditions outlined here one need hardly fear the presence of thrombus above the deep femoral or entering the main vein from it as is shown in Figures 1 and 2 A and B. However for full assurance many surgeons prefer section of the common femoral to interruption of the superficial femoral vein distal to the profunda branch. In any case one need not feel obliged to divide the opposite femoral vein a procedure required chiefly when bilateral signs are present and sometimes when no signs are discoverable in either leg to account for serious or repeated pulmonary embolism.

THE PROPAGATION OF A PARTLY ADHERENT NONOBSTRUCTIVE THROMBOSIS INTO THE FEMORAL VEIN THE EXTERNAL ILIAC VEIN AND HIGHER

This advanced stage may properly be called a subacute or even chronic form of quiet thrombosis. Though it approaches an obstructive thrombophlebitis it differs in several important respects. For edema is never a serious feature and embolism is rather common often recurrent. In other words since blood continues to flow past the thrombus soft masses of clot which are likely to be present at the proximal end of the process and may be detached at longer or shorter intervals. If of large caliber and in considerable gross quantity these masses are capable of plugging the pulmonary vessels with fatal effect. But in some instances repeated small embolism even over a considerable period seems to do comparatively little harm.

An unpredictable feature of the high in completely obstructive thrombosis is involvement of the deep branch of the femoral vein. When an adherent thrombus occupies the main channel one should take it for granted that the profunda also is partly filled with soft clot. Whether this is an independent process or has arisen from the primary disease is difficult to say. Frykholm indicates that thrombosis may be not only independent but primary here. Fine Frank and Starr give an account of a fatal case of this sort not sub-

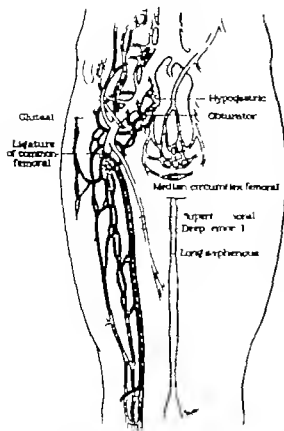


Fig. 3. A diagrammatic sketch showing the nature of the venous return from the right leg and the collateral circulation when the common femoral vein is interrupted.

jected to operation. In any event one is justified in assuming that in an advanced disease especially one of several weeks duration even though adherent thrombus is not found on the opening of the superficial femoral vein a dangerous thrombus may still be present in the profunda, ready to propagate into the common femoral an important consideration in treatment as will presently appear.

A rather characteristic sign of the advanced type of thrombosis is cyanosis. This varies in depth depending upon the degree to which the disease has penetrated the veins which ordinarily would offer collateral pathways especially in the thigh. For the thrombus in the main femoral and iliac veins, though by no means completely obstructive so permeates these vessels as to cause considerable venous congestion in the corresponding limb. And if

many collateral outlets are involved the limb must become in some degree cyanotic. This cyanosis is not necessarily evident when the patient lies in bed but becomes noticeable as the leg is made dependent. One can often make a diagnosis of an incompletely obstructive femorotibial thrombosis by letting the patient stand up for a minute or two whereupon the skin from the knee down will take on some degree of blueness. Edema, especially in a patient already confined to bed is strongly suggestive of such a process. If present it is usually confined to the ankle and lower leg.

With such signs in evidence certain others may or may not be discovered. There may be some slight thickening about the femoral vessels at the groin making the arterial pulsation at that point less distinct to the examining fingers than that of the opposite side, and in chronic cases, well advanced toward full obstruction a tendency to a spasmodic type of constriction of the femoral artery may very rarely be noticed.

A fairly frequent complication of the extensive process is thrombosis of some of the superficial veins. Usually a superficial thrombus, in either a varicose or an apparently normal vein, is an independent affair having little tendency to invade the deep vessels. But it may be secondary to a deep thrombosis. Thus when a superficial thrombus is noticed in the greater or lesser saphenous system and there is any reason whatever to suspect the presence of a deep process, the superficial thrombus is evidence for that process rather than against it. Barker Nygaard Walters and Priestley indicate that among 51 cases of postoperative, fatal pulmonary embolism in which the location of the venous thrombosis was clinically recognized it was found in the lesser saphenous vein on 30 occasions as compared with 18 in the femoral and iliac veins. They reason from this very common involvement of the lesser saphenous that since detachment of an embolus of any size from so small a vein is exceedingly unlikely the fatal embolus was probably a detached newly formed thrombus from the femoral or iliac vein which had not existed long enough to produce clinical signs or symptoms. Perhaps a better way to put the matter is to say that the superficial throm-

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bosis was probably secondary to a deep process in the calf, from which propagation of soft clot into the femoral vein had also occurred

As a background for the appearances which suggest an advanced disease there may or may not be present the familiar restriction of full dorsiflexion of the foot. Usually the posterior calf muscles will in some degree be irritable but a positive diagnosis can be made in the absence of a dorsiflexion sign or full tense calf muscles. In this connection it would be of great advantage if some corresponding signs were available to indicate thrombosis in the veins among the great muscles of the thigh. Actually no such signs have as yet been discovered. One can only infer that in the presence of a process of several weeks duration and especially when cyanosis in the lower leg is detectable thrombosis in the profunda femoris is very likely to be present

How high the advanced partly adherent but still nonobstructive thrombosis may have gone is usually difficult to say. It seems to progress farther on the left than on the right. Usually there is no thrombus of importance above the external iliac vein, an important consideration especially in common iliac and vena caval interruptions. Repeated embolism over a period of weeks months or years may properly be considered evidence of a high process from the proximal end of which fragments of moderate size are easily broken off

When an earlier thrombosis or thrombophlebitis followed by canalization and destruction of all valves in the femoral vein is known to have occurred the situation and progress of a recurrent thrombosis is particularly unpredictable. The venous return is already being cared for by collateral veins. Even an extensive process in the old canalized channel need cause no signs yet embolism may take place repeatedly in some instances. The recurrent thrombosis will usually have begun as usual in the calf where typical signs may perhaps be discovered. But whether or not such signs are present one should be prepared to find that the region from which embolism has occurred is high at or above the groin wherever in fact the vein has previously suffered disease. Embolism recurring over a

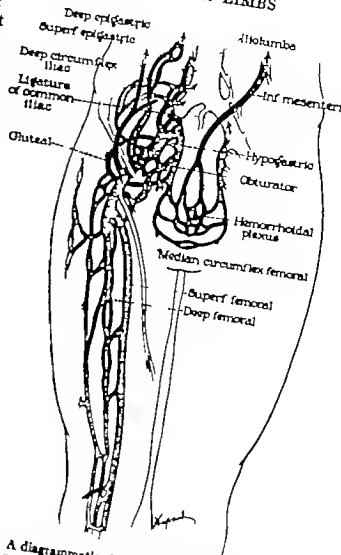


Fig 4. A diagrammatic sketch as in Figure 3 showing the very much more abundant collateral venous return when the common iliac vein is interrupted.

period of years is especially apt to originate in such a vessel.

To sum up the diagnosis of an advanced nonobstructive adherent thrombosis which has come to occupy the femoral system and perhaps some part of the iliac veins rests first in ambulatory patients on its chronicity. In these local signs of thrombosis or episodes of pulmonary embolism will have been noticed on and off for weeks or months. In post traumatic postoperative and postpartum cases and in thrombosis complicating any serious illness cardiac or other an advanced stage may be reached with far less warning and so far as can be ascertained from observation of the local signs in a relatively short time—a period of days or weeks. The suggestion that thrombosis has reached the groin or

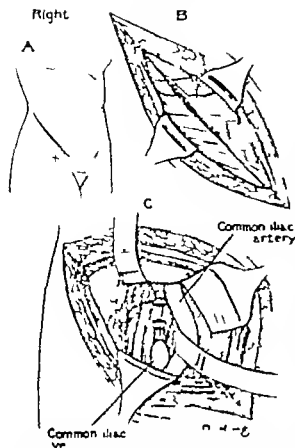


Fig. 1. A, B, and C. The extraperitoneal operative approach to the right common iliac vein, showing that the vein lies lateral to the artery which hardly requires the degree of retraction used. In C the vein has been doubly ligated with silk (including stitch above and below) and divided. A little more retraction, upward and medially could expose the vena cava.

higher is most likely to come from the presence of those signs of an advanced process which have already been described. Slight cyanosis of the foot and lower leg, evident as a rule only when the leg is dependent but sometimes detectable in the horizontal position, offers strong support. Persistent or recurrent edema of the ankle is helpful. Tenderness over the femoral vessels and superficial complicating thromboses are confirmatory. Phlebography may be of great assistance by demonstrating an irregular caliber and loss of valves in the femoral vein. On the other hand, if a picture is had even of only a few inches of normal femoral vein, one can be sure that no thrombosis has ascended from the lower leg.

Treatment is always operative, the real problem being the level at which the principal vein of the limb shall be interrupted. When the partly adherent thrombosis past which blood is freely flowing is discovered in the upper femoral vein upon exploration at the groin, the custom of most clinics has been to suck the soft thrombus out through a smooth glass tube as large as can be inserted into the common femoral vein, and if while the head of the table is raised and the flow from below is controlled by a guy ligature or rubber tube a good back flow of blood is then secured from above, the common femoral is sectioned between ligatures. This section cuts off any possible subsequent thrombosis which may enter from the profunda femoris but does not guarantee that a thrombus will not re-form in the external iliac vein or higher. It has been argued by those who advocate this procedure as a routine that even if thrombosis should recur at a higher level, emboli of large size are seldom cast off and a fatal embolism is very unlikely indeed. In any case, interruption should not be made in the superficial femoral distal to the profunda branch for serious if not fatal pulmonary embolism can surely occur from a propagating thrombus entering the common femoral from this vessel.

Evidence will now be presented that the situation just described should, if possible, be avoided. That is, an advanced nonobstructive thrombosis requiring extraction of a soft, partly adherent clot should not be attacked in the upper femoral vein but rather at a higher level. This will require a refinement of diagnosis not always attainable. The matter is discussed below.

INTERRUPTION OF THE COMMON ILIAC VEIN

Though interruption of the common femoral vein as already explained offers a considerable degree of protection against subsequent serious pulmonary embolism, it cannot give the assurance of a yet higher division, for example in the common iliac vein. But there is another reason why section of the common femoral vein under the conditions just outlined is undesirable. This is the unsatisfactory collateral circulation which follows upon such a division. The blood from the now fully

HOMANS QUIET VENOUS THROMBOSIS IN LOWER LIMBS

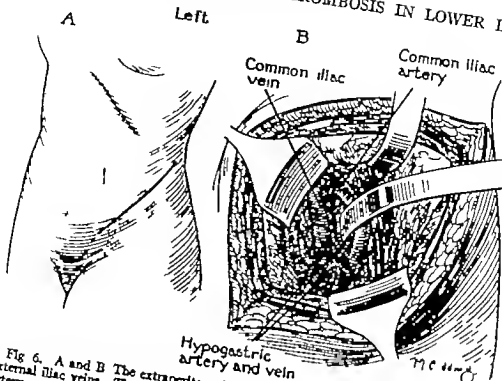


Fig. 6. A and B The extraperitoneal operative approach to the left common and external iliac veins. The vein lies mesial to the artery and at a deeper level. The of the vein is more difficult than on the right.

obstructed femoral system must find a passage through partly obstructed collaterals into the veins of the pelvis abdominal wall buttocks and so on by way of small and not particularly numerous channels Whereas if the common iliac vein is divided blood can escape via the common femoral through the deep epigastric, the deep circumflex iliac and particularly through the hypogastric vein By way of this last channel it may pass through rectal vessels into the inferior mesenteric vein or to the opposite side of the pelvis and in women an additional collateral field is offered by the uterine and ovarian veins The difference in the collateral pathways offered by interruption at these two levels is shown in Figures 3 and 4 which speak for themselves Backing up these anatomic considerations clinical experience indicates that while serious venous congestion and swelling sometimes follow in the superficial and deep femoral systems are partly filled with adherent thrombus section or ligation of the common iliac vein seems to leave no such troubles behind As a result of an experience now covering 14 such interruptions these conclusions seem justified

The question of the greater difficulty in performing the higher operation now comes up First as regards the anesthesia It will probably be agreed that division of the superficial or common femoral vein can very easily be performed under procaine infiltration The same is hardly true of the common iliac operation The ideal approach is of course the extraperitoneal one very much like exposure of the ureter at the pelvic brim The incision commences above in the flank and is carried down parallel to the inguinal ligament nearly as low as the inguinal canal. For thus a nerve block with novocain is perfectly adequate but unfortunately after the peritoneum has been pushed mesially and retraction is made to clear the iliac vessels there is a drag on the intestinal mesentery which is decidedly painful. This pain quiets down while retraction is steady but it is certainly a disagreeable feature of the procedure Thus a local anesthetic is not easy to use especially for an operator not accustomed to it Spinal anesthesia will probably be preferred an added risk perhaps in patients having cardiac disease and especially high blood pressure Very likely also this anesthesia increases the danger of pulmo-

nary embolism on the operating table due as O Neil has suggested to the possible detachment of an embolus while the patient's back and thighs are flexed during the insertion of the spinal needle. For such reasons a general anesthetic will usually be required.

The second increased hazard of the high interruption is due to disturbance of the retroperitoneal lymphatics. One sometimes notices in operations for thrombosis hypertrophied lymph nodes which lie upon and about the vessels of the pelvic brim. Should these be receiving infectious material the manipulations required for ligation or division of the vein will perhaps contaminate the retroperitoneal space.

A third risk lies in the danger of separating from the common iliac artery and from the tissues behind it the great vein which especially in the case of an old thrombophlebitis is often very easily torn. The same is in some degree, true of the femoral under similar conditions, but the femoral vein is far more accessible and easily handled. One is conscious especially in freeing the left common iliac (Fig. 6)—it lies median to and deeper than the artery not lateral to it as on the right—that if it were torn hemorrhage would be serious and difficult to control. Moreover if one is actually to divide the vein and particularly if one is to look for a contained thrombus one must free it for some distance so that it can be opened between guy ligatures and then ligated by double ties above and below of which the ones next the cut ends shall be transfixing stitches. Such an operation of course, consumes time and effort and increases the risk of tearing the vein. One is tempted therefore, to ligate without dividing a procedure offering no view of the vein's contents and less likely than division to obstruct it permanently. Possibly also failure to divide the vein encourages the persistences of such vasoconstriction as may be present in the venous tree of the limb.

All these disadvantages, of which the risk of tearing the vein is the most serious seem to be outweighed by the finality with which the higher interruption of the common iliac especially obstructs the vein *above* the usual source of embolism including processes in the

profunda femoris, and by the excellence of the collateral circulation. Until one becomes accustomed to it, one can hardly believe that an operation seemingly so radical, leaves so little venous congestion behind.

As between division of the common and of the external iliac vein the former operation is obviously preferable. This is in great part due to the availability of the hypogastric vein as a collateral when the common rather than the external, iliac vein is interrupted. But the common is actually the more accessible. On both sides, the external iliac vein lies medial to the artery and at a deeper level. It is always somewhat difficult to isolate. Even on the left where the common as well as the external iliac vein lies medial to the artery the common owing to the nature of the extra peritoneal approach is the more readily exposed. And on the right side the difference is even more marked. For the right common iliac vein lateral to the artery and easily separated from it is remarkably accessible (Fig. 5). It is reasonably so in the obese patient.

Examples of common iliac section and ligation have previously been published (14). The operation has been used when a reasonably certain diagnosis of thrombosis of a non obstructive sort rising as high as, or higher than the inguinal ligament, has been made. In many instances, embolism had already occurred. In others, it had seemed to be threatened. In yet others there had been several attacks of thrombosis without embolism and the attempt to prevent further recurrence seemed indicated.

As yet little information has been secured in these high interruptions as to the proximal extent of the thrombosis. In the 6 right iliac sections, the vein was explored 5 times and in no case was thrombus encountered in the common iliac. In the 8 left sided operations, the vein was usually ligated without opening it. On one occasion, it was explored without finding a thrombus. On 5 others, the vein appeared to be the scene of an old thrombosis which had left its wall discolored and, to the operator's mind, friable. In each case a fresh thrombus was believed but not proved to be present. Full exposure and exploration with retraction upon guy ligatures, was thought to

carry too great a risk of tearing the vessel. Simple ligation in continuity even though made about a possible soft thrombus seemed the safer procedure. In the 2 other cases a seemingly normal vein was ligated without exploration. Nevertheless the impression has been gained that thrombosis is far more likely to advance above the external iliac vein on the left than the right. Whether the attempt to suck out soft thrombus through the opened vein is worth the added risk which the procedure entails is debatable. Probably on the very rare occasions when much pulmonary embolism has already occurred the attempt will be desirable in order to guard against further immediate detachment¹ but these are also the occasions demanding the very simplest, shortest and most bloodless operation. Further experience is needed to settle this problem.

INTERRUPTION OF THE VENA CAVA

This operation is probably indicated in the presence of bilateral thrombosis which is believed to have risen in the main venous stem on both sides to or about the level of the inguinal ligaments. It is certainly to be preferred to separate ligation of each common iliac vein and is decidedly less radical than it sounds. For it really offers very little more obstruction to the venous return from either leg than division of the common iliac vein on the corresponding side. Actually there are no or only very small lateral branches between the point at which a common iliac is ordinarily divided and the point a few centimeters proximal at which the vena cava itself is interrupted. Its only disadvantage so far as the return circulation from each leg is concerned is that it prevents the shunting of blood from one side of the pelvis to the other across the midline—a matter relatively easy when only one common iliac vein is shut off.

As yet experience is insufficient to determine the state of the venous return from the legs after occlusion of the lower vena cava when a fairly extensive thrombosis is present in both legs. Some information however is available as to the state of the circulation when vena caval ligation has been used for septic thrombosis in the uterine and ovarian veins. Collins, Jones and Nelson indicate in a preliminary report that following such ligation the venous pressure in the legs is raised only for a short time for it falls rapidly in the first weeks after operation. Indeed the problem involved has been whether or not the operation successfully ends the escape of septic material and emboli from the pelvis rather than whether or not vena caval interruption is compatible with a satisfactory venous return from the lower limbs. Certainly occlusion of the vena cava must cause far more venous congestion when performed for an advanced venous thrombosis in both legs than for even an extensive process in the veins within the pelvis. In all cases the operation should be used only by those familiar with the isolation and ligation of large vessels. It is not yet indicated as a routine when the situation and source of embolism are unknown.

Technically the procedure is not at all difficult. The vena cava lies to the right of the aorta in the lower lumbar region and the incision used for exposing the right common iliac vein extraperitoneally offers an entirely adequate exposure. It is only necessary to sweep back the peritoneum a little farther toward the midline and slightly higher in order to obtain access to the vena cava. As in the case of the iliac veins themselves the vena cava may be fixed rather firmly at some one point though much of its circumference is easily exposed. It may be not only difficult but dangerous to clear enough of it to pass rubber tubes or guy ligatures about it to incise it and suck out thrombus but it should not be difficult to pass a curved smooth clamp around it being careful to hug the surface of the vertebrae posteriorly and one or two ligatures of good sized braided silk should offer a satisfactory interruption.

It must be understood that this extraperitoneal procedure is only appropriate to cut off

¹When this paper was prepared, case report () dealing with this very matter has come to hand. A soldier 33 years of age, on active service and relieved from duty because of fever and thoracic signs, was found to be suffering from two attacks of pulmonary embolism, the source being an advanced thrombosis which had caused minimal signs in the left leg. At operation, tubing was passed about the lower vena cava and both common iliac veins. Soft thrombus projecting from the left common iliac into the vena cava was extracted, and the common iliac vein secured close to the vena cava. After one more small embolism, the soldier recovered and suffered very little subsequent edema of the limb. Undoubtedly severe venous thrombosis and embolism occurs in young men of the military services, whether or not injured or wounded, than is generally supposed.

thrombotic processes arising from the legs. In case of embolism from a thrombosis which is believed to be established in the uterine and ovarian veins, it must necessarily be insufficient for in that case the ovarian veins also require division. Under such circumstances, a transperitoneal approach must be made preferably a midline incision beginning somewhat above the umbilicus and giving sufficient room to expose both the vena cava and the ovarian veins.

CONCLUSIONS

1. Thrombosis of a quiet type (phlebotrombosis) commencing in the deep veins below the knee is the source of most nonobstructive processes threatening pulmonary embolism as well as most obstructive inflammatory ones responsible for painful swelling of the whole lower limb (thrombophlebitis).

2. Thrombophlebitis of the fully obstructive type presents no satisfactory indication for operations but rather for release of the associated vasoconstriction by lumbar sympathetic block.

3. It is desirable and usually possible to distinguish an early stage of quiet deep venous thrombosis when the process is still confined to the lower leg or has given rise to an untached propagating thrombus in the popliteal and femoral veins threatening pulmonary embolism. The signs of such a state are discussed and the clear indication for femoral interruption to forestall or stop embolism and prevent the development of phlegmasia alba dolens is pointed out.

4. An advanced stage of quiet deep venous thrombosis more or less adherent but not obstructive can also be distinguished. Its signs are discussed. Thrombosis will often have propagated above the inguinal ligament into the external and occasionally especially on the left the common iliac vein. With such a process thrombosis of the deep veins among

the muscles of the thigh (profunda femoris system) is usually associated. Thrombosis in these deep veins may even be present when no thrombus is found on exploration of the superficial femoral vein below the profunda.

5. The advantages of interruption of the common iliac vein for all such advanced quiet venous thromboses are discussed and the operative procedure for both the right and left limbs is described.

6. Some observations upon interruption of the vena cava are made.

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CANAVALIN, A NEW ENZYMATIC BACTERICIDAL AGENT

Preliminary Report

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AS a result of the author's previous work a new enzymatic bactericidal agent called canavalin has been discovered. The present paper gives the method of its preparation, experimental data showing its *in vitro* action, and certain preliminary information as to its clinical use in patients.

Experimental work leading to the product canavalin has been carried out by me for about 10 years. The sequence of progress was as follows: First it was noted that the blood serum of animals including man contained a variable amount of a substance which inhibited hemolysis of red blood cells. It became apparent that the quantity of this substance in the blood could be increased by giving thiamin chloride. After considerable effort methods were successfully devised for isolating this substance from blood serum for making the substance *in vitro* and for isolating it from this last named source.

At this time the function of the substance was obscure. Its physical characteristics were those of a co-enzyme (4, 5, 6, 7). With this experimental lead various enzymes were investigated in an attempt to find the enzyme with which this unknown co-enzyme functioned. Eventually it became obvious that the substance acted as a co-enzyme against polysaccharides (starch, glycogen, etc.) when an extract of jack bean meal was a part of the reacting mixture.

At this point in the search it was recalled that Avery and his co-workers (1, 2, 3) found that certain substances of bacteria, particularly bacteria of the pneumococcus group and the Friedlaender's group, are of a polysaccharide nature. When emulsions of living bacteria were substituted by me for starch as substrates, oxidation occurred as readily as with starch or glycogen as shown by an oxygen uptake from the air in the closed system of a

modified Warburg instrument and the development of substances in the liquid contents of the reacting chamber which reduced Benedict's and Fehling's solutions. Culture of the residual mixture showed the bacteria to be dead (Figs. 1 and 2). This enzymatic action against bacteria was considered extraordinary because the enzymatic action occurred against living organisms. It is well known, of course, that dead bacteria are susceptible as substrates to enzymatic action. It was also considered extraordinary that oxidation occurred from oxygen of ordinary air. It is the author's belief that this bactericidal action of canavalin results from an oxidation of polysaccharides in bacteria and that the oxidation of these substances destroys the life of the organisms. Emulsions of the colon bacilli, pneumococci, Friedlaender's bacilli, and staphylococci were used as substrates with similar oxygen uptake. Cultures of the bacterial emulsions mentioned were sterile. When oxygen was substituted for air in the closed system there was some increase in the speed of the reaction, but the difference from that obtained with atmospheric oxygen was not striking. When nitrogen was substituted there was no reaction.

The immediate thought was that since the enzyme system reacted in an artificial mechanical arrangement to kill bacteria, perhaps it might be of value in the treatment of infectious disease, that it might also destroy bacteria infecting the body. The results of clinical use of the material are summarized later in this paper.

Canavalin is a mixture of an enzyme and a co-enzyme solution, separately extracted and mixed. The enzyme portion is an extract of jack bean (*canavalia ensiformis*—8). It also has been extracted by me from soy beans, liver, and white potatoes. The jack bean is the best source. The co-enzyme portion of canavalin is associated with the vitamins of the water soluble B group. Thiamin and ribo-

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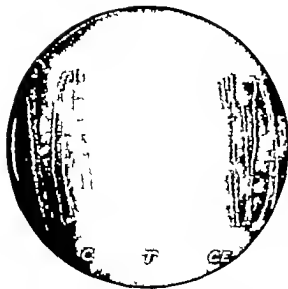


Fig. 1. Subculture of colon bacillus after treatment with canavalin. C, control, same as T but untreated by canavalin. CE, control, original culture of colon bacillus.

flavin are used to produce *in vitro* a supply of co-enzyme. This co-enzyme is called by me 'vitatropin' and has the physical characteristics usually possessed by a co-enzyme—thermostability, filterability and the property of being precipitated from a watery solution by an organic solvent. It is an interesting fact that both enzyme and co-enzyme have been found by me to be present in normal blood. Quantitative tests for content of both these substances in the blood have been devised.

The oxidative canavalin reaction with bacteria as a substrate takes place with equal ease when the medium contains milk or blood as when the medium is a watery solution. The hypothetical importance of this is that the blood has been shown to contain catalase-like substances which inhibit enzyme reaction. It can be assumed therefore that the oxidative reaction in question is not inhibited by the catalase-like substance in the blood. Members of both gram-negative and gram-positive groups of bacteria are oxidized by canavalin although gram-positive seem to be more susceptible to its action (Fig. 3).

Action of the enzyme portion of canavalin does not take place unless the co-enzyme is present. Since the co-enzyme (vitatropin) is normally present in blood serum, the enzyme

will always give some reaction in the presence of blood and a suitable substrate.

The apparatus used for determining enzyme action is a modified Warburg apparatus. This enables one to measure in millimeters positive and negative pressure in a glass capillary 'U' tube which is connected to a closed system where the enzymatic action occurs. Mechanical controls provide constant temperature and agitation. Brodie's solution is used in the apparatus as the labile liquid.

PREPARATION OF CANAVALIN

Soy bean or jack bean flour is extracted by a mixture of water and an organic solvent such as alcohol. A clear supernatant fluid is separated by centrifugation, precipitated by acetone and the supernatant fluid again recovered by centrifugation. A solution of a heavy metal salt is added to this supernatant fluid. The enzyme forms hypothetically a heavy metal enzyme combination. The metallic portion of the combination is removed in the usual way as an insoluble precipitate, leaving the enzyme in solution. To this enzyme solution is added a solution of vitatropin (co-enzyme). The co-enzyme portion has been previously discussed by me as 'inhibitory substance and OBT'. It has now been given the name vitatropin. Vitatropin is extracted from a mixture of a cellular tissue and thiamin chloride which has been allowed to stand for a week with frequent shaking and daily heating for 1 hour at 70 degrees C. After this time it is absorbed on insoluble barium sulfate and eluted with a weak ammonia solution, from which it is crystallized. The method of preparation of vitatropin is entirely empirical. Canavalin is prepared by mixing the enzyme and co-enzyme solutions. The optimum proportions of enzyme solution to co-enzyme solution is as yet not determined.

IN VITRO STUDIES OF CANAVALIN

An action curve of a given batch of canavalin was plotted (Fig. 4). The points determined were four. The abscissae represent amounts of canavalin solution in cubic millimeters as transposed to linear measurements, the ordinates the height of negative pressure in cubic millimeters of Brodie's solution (trans-



Fig. 2. a, *Staphylococcus aureus* after treatment with canavalin. C Control, same as T without treatment with canavalin. C.E. Control, original culture of *staphylococcus aureus*. b *Colon bacillus*. T Subculture of *colon bacillus* after treatment with canavalin. C Control, same as T without treatment with canavalin. C.E. Control, original culture of *colon bacillus*.

posed, of course to linear millimeter measurements) In order to determine death point cultures of the reacting media were made at each point after completion of enzyme action. The points determined were

Canavalin solution	Oxygen uptake
0.010 c.c.	35.0 mm.
0.030 c.c.	60.0 mm.
0.050 c.c.	95.0 mm.
0.100 c.c.	140.0 mm.

The factors of the enzyme reaction were: 0.2 cubic centimeter of *colon bacillus* emulsion; the washed emulsion containing nine billion living organisms per cubic centimeter; 0.5 cubic centimeter of phosphate buffer (pH 7.8) water sufficient to make a total volume of 2.5 cubic centimeters. Canavalin solution in amounts stated above. Total volume of instrument (closed over all) 15.0 cubic centimeters. The instrument used was a modified Warburg.

The conclusion was that the minimum quantity of canavalin solution necessary to cause death of bacteria in the factors used was that amount which caused 60.0 millimeters of oxygen uptake. That is death of *colon bacilli* occurred only at the last 3 points plotted on the curve, namely 60, 95 and 140, while the cultures taken at point No. 1 showed growth. According to this quantitative method it has

been possible to prepare canavalin of ascertained killing dosage.

It was considered desirable to compare the bactericidal power and oxygen uptake of canavalin *in vitro* with other agents which might be similar in action. For this purpose sulfadiazine and penicillin were selected. It was found to be impossible however to make such a comparison since sulfadiazine produces no oxygen uptake with either bacteria or polysaccharides such as starch. Penicillin in great concentration produces a slight oxygen uptake when used against bacteria with vitatropin as a co-enzyme, but in great dilution shows no reaction. If penicillin depended upon oxidation of bacteria for its evident beneficent action, one would expect some oxygen uptake in high dilution of penicillin. A weak solution of penicillin in an enzyme reaction chamber containing only bacteria emulsions and buffer solution was however negative for oxygen uptake.

Strangely enough while sulfadiazine gave no evidence of polysaccharide oxidation when used alone with polysaccharides, there was marked stimulation of canavalin oxidation by very small quantities of sulfadiazine. e.g. — 0.001 milligram of sulfadiazine in a total volume of 2.5 cubic centimeters increased the oxygen uptake of canavalin from 62.0 milli-

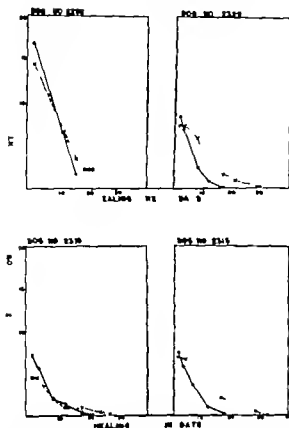


Fig. 4. Graphs showing 4 of the animal experiments. Note that the treated curves (straight lines) cross the control curves (crossed lines) early in the course of treatment. This is suggestive of the fact that tissue extract may influence granulation tissue as well as final epidermization.

effect that the following laboratory and clinical experiments were done.

The material to be tested was prepared as follows. Sterile adult sheep hearts were cut up and placed in a blender with Tyrode solution and finely minced. This mixture was allowed to stand in the refrigerator for approximately 24 hours, and then centrifuged. The supernatant fluid was decanted and placed in convenient sterile flasks. This extract, when kept in the icebox, was found to maintain its growth promoting activity for at least 1 month. The growth accelerating properties of these extracts were tested from time to time on cells growing *in vitro* by a standardized method.

EXPERIMENTAL STUDY

Normal healthy mongrel dogs of either sex and of any age were used as experimental animals. Under intravenous nembutal anesthesia, sym-

metrical bilateral circular areas of skin were excised on either side of the lower chest, in some instances with sterile precautions and in others not. All bleeding points were clamped and tied with fine silk, and sterile gauze dressings were applied. At the outset it was obvious that great difficulty would be encountered in maintaining intact dressings over these lesions in active animals. Bandage and tape were found inadequate and when reinforced with fenestrated plaster jackets, interfered with the animal's nutrition, respiration, and other vital functions. Finally a method was devised which consisted of using Michel skin clips to hold the dressing to the animal's skin and covering this with elastic (Ace) bandages. For the most part this constituted a satisfactory method. The original dressing was left intact for 4 to 5 days at which time it was found that in most animals granulation tissue was present and the skin edges were firmly adherent to the underlying subcutaneous tissue so that the size of the area did not vary with movement of the skin.

At this point measurement of the wound areas was performed by the method described by Carrel, i.e., cellophane tracings were made and transferred to white paper and these areas were then measured with a planimeter and expressed in square centimeters. Inevitably the wounds were of different size at this stage, there being a 2 to 50 per cent difference. In every instance the larger area was used as the 'treated' side and the smaller as the control. After the initial period, treatment was carried out every 2d day as follows. Saturated Dakin's packs were applied for 5 to 10 minutes to both wounds on each animal and the residual solution was then washed off with copious amounts of saline. On the larger or 'treated' side a gauze sponge saturated with tissue extract was applied and on the control area, a saturated saline sponge was used. Both wet dressings were covered with sterile cellophane so as to prevent leakage and the outer dressing was secured. Measurements were taken of the change of size of each wound until healing had occurred. Contralateral wounds were plotted on graph paper with the abscissa measur-

TABLE I.—EXPERIMENTAL RESULTS

No. of Dog	Healing time in days of experimental wounds	Healing time in days of control wounds
264	3	
266	6	20
260	3	
264	6	5
266	20	43
3 5		3
3 9	20	26
3 5	7	30

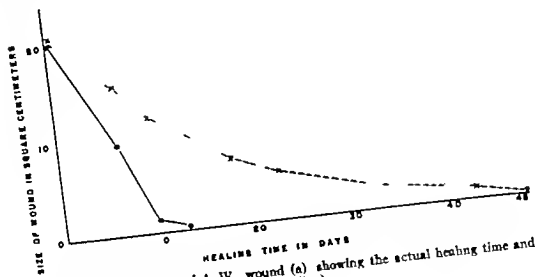


Fig. 2. From the case of A. W. wound (a) showing the actual healing time and the expected healing time (DuNouy broken line)

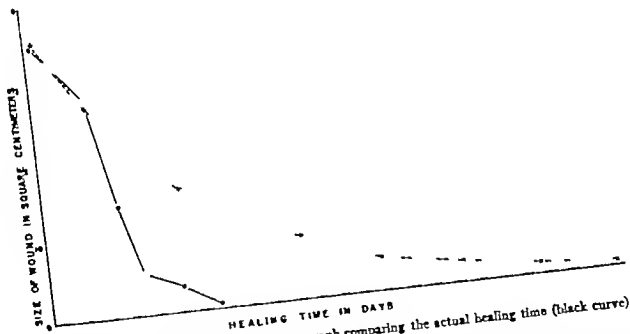


Fig. 3. Case of A. W. wound (b) This is a graph comparing the actual healing time (black curve) with the expected healing time (DuNouy broken line)

ing time and the ordinate the size of the wounds. Ten dogs or 20 wounds were so treated. Results (Fig. 1) Of the 10 animals, 2 died in the course of treatment from ruptured tracheae following a dogfight. However significant results were obtained before they were lost to the experiment. Eight animals or 16 wounds, were followed to complete healing and in every instance the treated side was healed before the control regardless of how much larger the latter was at the onset of treatment. Expressed in percentage the treated sides healed on an average of 40 per

cent faster than the controls. In the 2 animals who died the treated sides were respectively 50 to 40 per cent smaller than the control on the last measurement although they were larger than the control at the beginning of treatment.

CLINICAL STUDY

Carrel and Hartman, in 1916 published work based on observations in man and animals in which they pointed out that the healing of wounds followed a very definite pattern, with the rate of cicatrization being geometric in character readily

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the control curve. Of the remaining 3 x wound was healed in the same time and 1 in a slightly longer period than the control.

TABLE II.—CLINICAL RESULTS

Patient:	Actual healing time in days	Expected healing time in days
S. G.	30	40
J. T. (1)	6	14
J. T. (2)		
A. H. (a)		
A. W. (b)		
E. J.		
M. K.	3	70
D. R.	38	48
F. H.	7	70
E. K.	6	38
	5	40
		30

In evaluating these results, some emphasis should be placed on the fact that the coefficient as used in the DuNouy formula had been calculated by him for patients only up to the age of 40 years. In calculating the control for 6 of the wounds shown in Table II, the coefficient for 40 years of age was used despite the fact that the patients ranged from 48 to 70 years of age. For the 3 patients, (A. W. S. G. J. T.) underlying circulatory disturbances were present. In the 3d case (J. T.) ulcers were the result of x ray therapy for calluses, and the wounds on the plantar surface of the foot following excision and debridement, extended to the phalangeal heads. Covering of the exposed bone required a major portion of the healing time.

It should also be pointed out that the presence or absence of infection, the degree of contamination and possibly the type of invading bacteria have a definite effect on the efficacy of the extract and hence on the healing of a wound. These observations were made in both animal and clinical cases since when gross infection was present, the wound remained stationary in size until the infection was controlled. Similar observations were made by Carrel. The presence of certain bacteria probably destroys the action of tissue extract.

SUMMARY AND CONCLUSIONS

1. Previous work with the use of tissue extract in the treatment of wounds is reviewed.

2. Some facts concerning the nature of the cell growth promoting action of adult animal tissue extract are discussed.

3. Experiments carried out on 10 dogs with bilateral wounds are described, with a suggestion as to a satisfactory type of dressing for treating wounds in active animals. Results showed that wounds treated with tissue extract healed faster than the controls.

4. Eleven clinical wounds favorably treated with tissue extract are reported. The healing time for 8 out of 10 lesions was significantly shorter than the expected healing time for normal wounds of similar size when calculated by the DuNouy formula.

5. Further clinical work is in progress at the present time, as well as studies to determine the nature of the growth promoting principles in animal tissues.

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EDITORIALS

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CLASSIFICATION OF CHRONIC CYSTIC MASTITIS

A LAMENTABLE state of confusion exists among surgeons and pathologists alike as to views and classification of chronic cystic mastitis. The inconsistencies and variables in the disease are largely responsible for this lack of agreement but all must agree that assimilation of knowledge which would eliminate needless operations and dictate correct surgical procedures when operation is indicated would obviously be highly desirable. During the years when there has been so much disagreement and confusion in our conception of chronic cystic mastitis one very important point however has been clarified namely the relationship of chronic cystic mastitis to cancer of the breast. With practically no exceptions all writers (surgeons or pathologists) who have offered their opinion on this subject during the past several years have expressed their firm belief that cancer may and does develop in areas of chronic cystic mastitis even though there is as yet no

means of determining just how often and in what types of chronic cystic mastitis this may occur. However the mere establishment of this relationship as a fact paves the way to a more accurate understanding of the various types of lesions. In our opinion¹ any conception or classification of chronic cystic mastitis must therefore correlate pathologic with surgical knowledge and likewise attempt to identify the type of lesions which might develop into cancer. Complete fulfillment of this last ambition will naturally be very difficult to realize chiefly because a vast majority of lesions exhibiting the nodularity of chronic cystic mastitis are excised thereby not allowing us to determine just how many might have developed cancer and at what date. Moreover even though we may have observed cancer develop in a breast which was the site of chronic cystic mastitis we will have had the opportunity to know what type was responsible for the malignant change only when we had performed biopsy or incomplete removal months or years previously. Such situations develop or are created only occasionally and correctly so. Nevertheless sufficient facts are now apparently available to allow the development of a more satisfactory classification which is herein described. Introduction of new terms is carefully avoided since they frequently add confusion old familiar terms are used and an attempt is made to adhere closely to their definition.

Before a pathologic classification of any given disease can be attempted the various changes observed in the different types of that disease must be reviewed and analyzed. A

¹Cole W. H., & Rouster L. J. The Breast, Lewis & Hirsch, Pract. of Surgery Hagerstown, Md. W. B. Saunders Co. (In Press) Chapt. 9, Mastitis, p. 2, Surg. (In Press).

SURGERY GYNECOLOGY AND OBSTETRICS

study of numerous specimens of chronic cystic mastitis reveals 5 or 6 major histologic features at times, 2 or 3 or more of these may be observed in a single section, but with few exceptions one of these pathologic changes will predominate. *Fibrosis* is encountered in practically all specimens in some it is so pronounced that the glandular elements may have been displaced to a pronounced degree. By the next most common change observed. This hyperplasia may affect the glands themselves, or the ducts usually if one structure is increased in number the other will be also but not necessarily so. The hyperplasia usually takes place in an orderly fashion with little or no change in cellular characteristics although dilatation of the ducts or glands is commonly observed. Not infrequently the hyperplasia develops with changes which are of a precancerous nature i.e. there is much variation in size and shape of the cells. The cells may be markedly increased in number—layered or plicated their nuclei are much larger and darker (hyperchromatic). As stated there may be a variable degree of dilatation of the ducts or glands particularly the former. On certain occasions these cyst like spaces may attain a size several centimeters in diameter when they are designated as *cysts*. Through out certain sections *lymphocytic infiltration* is noted to a variable degree but no significance can be ascribed to this change. While factors in pathogenesis are not here discussed it should be noted that endocrine imbalance is probably the most important known agent involved. When the pathologic changes here described are correlated with the clinical findings the following four distinct classifications may be identified.

1. *Adenofibrosis* In this lesion the predominant change is fibrous. Glandular elements are present in decreased numbers occasionally they have been crowded so much by the deposition of fibrous tissue or have become so atrophied that only an occasional distorted gland is seen. Likewise the ducts are usually fewer in number cystic dilatation is uncommon and is not considered a part of this lesion. Grossly the breast is firm but resilient the glandular elements are so sparse that the cut surface is fairly homogeneous and presents an ivory white surface because of the density of the fibrous tissue. Clinically the breast is felt usually as a disc-shaped indurated organ although the firmness may be limited to one quadrant. The surface may be slightly roughened rarely are there present solitary nodules of significant size. Tenderness is slight as is also pain. Adenofibrosis was encountered in 22 per cent of our cases. The average age was 37.4 years.

2. *Benign parenchymatous hyperplasia* The predominant microscopic feature of this lesion is a proliferation of the ducts glands and connective tissue stroma particularly the ducts. Considerable epithelial and secretory debris will be found in the dilated ducts and glands. The epithelial changes are limited to an increase in number—with layering and occasional plication. Hyperplasia may be found but no neoplasia. Occasionally the hyperplasia involves primarily the glands, which overrun the microscopic field we apply the term *adenosis* to such lesions since by definition no other term appears more appropriate. The increase in connective tissue is variable but is never as pronounced as in adenofibrosis. Gross examination or palpation of the breast reveals numerous nodules varying from 5 to 15 millimeters in diameter. These nodules are firm but resilient. Occasionally cord like structures representing indurated ducts are found. No hard friable areas are found. On cut section the larger ones contain material which may vary in color and consistency from thin

amber colored fluid to thick yellow brown pasty material. In our series 46 per cent of the cases were classified in this group the average age of the patients was 43.7 years.

3 *Precancerous hyperplasia* The hyperplasia in this group resembles that seen in cancer. There is considerable variation in size and shape of the cells. The nuclei are hyperchromatic. The cells are layered and plicated forming numerous papillary processes. Mitoses are common. Some of the ducts may be completely filled with epithelial cells. Even though cellular activity is pronounced nowhere is there evidence of invasion or of the breaking through of normal barriers. The lesion cannot be classified as possessing permanent benignity nor can it be considered malignant even though development of cancer appears possible or even probable. Palpation of the breast in such cases will reveal no characteristics different from those described under benign parenchymatous hyperplasia. In other words there is no way to differentiate the two groups clinically. On cut section occasional small hard areas with occasional papillary formation may be found. As in benign parenchymatous hyperplasia small cystic spaces are seen. The smaller ones contain thick, gray pink or brown exudate whereas the larger ones may contain thin straw colored fluid. The microscopic section still remains the only mechanism of distinguishing this lesion from benign parenchymatous hyperplasia. Of the entire series 22 per cent of the cases were classified in this group the average age was 41.6 years.

4 *Cystic disease* In this type of lesion the cystic spaces may attain a size equal to 4 to 6 centimeters in diameter. They may occur singly but are usually multiple. In this group are classified the blue-domed cysts of Bloodgood. Fluid in the cyst is usually thin straw colored or brown and frequently cloudy. A variable

amount of connective tissue is present between the cysts. The cysts are usually palpated as firm smooth tumors but occasionally are mildly fluctuant. The breast tissue itself is atrophic. The lining of the cyst is smooth. Microscopically the walls are composed largely of connective tissue and may vary considerably in thickness. There is a lining of flattened cuboidal cells. Occasionally these cells may be layered and appear to be degenerating. Glandular structures are much decreased in amount. Ten per cent of our series were classified in this group the average age was 46.6 years.

Clinical manifestations aid in the differentiation between the four different types described but accurate identification is not possible until the microscopic sections are seen. Pain and tenderness may be present in all types, but in general is less prominent in adenofibrosis and cystic disease. Findings on palpation have already been discussed. In general a flat indurated disc shaped breast with only slightly roughened surface is indicative of adenofibrosis. Large multiple firm or fluctuant nodules indicate the presence of cystic disease whereas diffuse nodularity (nodules varying from 5 to 15 mm in diameter) is typical of benign parenchymatous hyperplasia or precancerous hyperplasia. Seldom can differentiation of the two last named lesions be achieved without microscopic sections.

As stated surgeons and pathologists alike now agree that chronic cystic mastitis may give rise to cancer however as yet there is no method of determining which types are most prone to become malignant. One of the purposes of the classification herein discussed is to attempt to determine which type of chronic cystic mastitis may become malignant. If this point were clear we could avoid operation in certain types in which symptoms were negligible and on the other hand might prevent

cancer by the removal of the dangerous lesion while in its early stage. From our studies it appears that a malignant lesion rarely develops in adenofibrosis and cystic disease. Both benign parenchymatous hyperplasia and precancerous hyperplasia may become malignant; the latter is much more dangerous than the former. In our opinion a great number of those lesions exhibiting precancerous hyperplasia would develop into cancer if treatment were delayed long enough. As intimated previously, an accurate estimation of the percentage probability of malignant change will never be known, since most lesions are removed surgically a short time after detection; moreover, it is impossible to tell from microscopical examination of a cancer just what type (if any) of chronic cystic mastitis existed previous to the development of the cancer. We wish to emphasize, however, that on many occasions areas of chronic cystic mastitis (one of two types of hyperplasia herein discussed) are found adjacent to cancer.

Our study has led us to the following conclusions regarding therapy. Since adenofibrosis and cystic disease rarely develop into cancer, operation need not be advised in these lesions unless symptoms are significant. Since it is impossible to distinguish benign parenchymatous hyperplasia from precancerous hyperplasia clinically, and since either may become malignant, excision will be advisable in these lesions. Excision should be liberal, a large wedge-shaped segment being removed, since dangerous areas of hyperplasia may exist in adjacent areas which are not palpable. When microscopic section reveals precancerous hyperplasia in the segment removed, we are *definitely* of the opinion that the entire breast (not including the pectoral muscles) should be removed, since the lesion is almost certainly diffuse and if left untreated long enough the probability of development of cancer is great. No surgical therapy is indicated in the remaining breast unless evidence of chronic cystic mastitis is present. WARREN H. COLL.



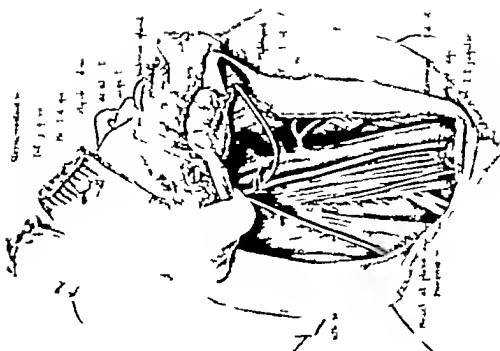


Fig. 1. Lateral view of the head showing the jaw and neck area. Fig. 2. Medial view of the head showing the jaw and neck area.

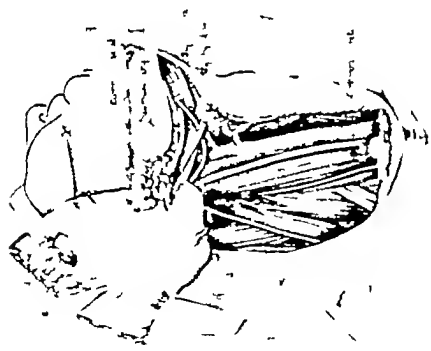


Fig. 1. Lateral view of the head showing the jaw and neck area. Fig. 2. Medial view of the head showing the jaw and neck area.

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NECK DISSECTIONS FOR METASTATIC CARCINOMA

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BLOCK surgical excision of the lymphatic bearing tissues of the neck will probably cure more patients with metastatic carcinoma in this area than will any other procedure known at this time. The operative mortality is low, the resultant alterations in appearance and function are small (Figs. 1 and 2) and the technical difficulties are not so great as they are sometimes estimated.

Carcinomas of the mouth and lips seldom metastasize below the clavicles even terminally; nearly all fatalities come from deep or widespread local extension or insurmountable neck involvement. The use of neck dissections on these patients when possible and when the local lesions are probably controllable is a rule that can be followed with deviations in some instances rather than its use as a last consideration.

Data concerning the rationale of the operation criteria for its performance, results, choice of the type of dissection and other forms of treatment have been reviewed in a recent paper (4). Taylor and Nathanson's book is an excellent source of information regarding the anatomy of the cervical lymphatics and the probable direction of spread from various locations in the mouth and the book contains other relevant material.

Central lesions such as carcinoma of the lower lip or of the floor of the mouth or alveolus anteriorly tend to metastasize to both sides of the upper part of the neck. More laterally situated lesions on the side of the tongue or farther back on the alveolus or floor of the mouth or on the buccal mucosa, are apt to spread unilaterally to the deep superior cervical nodes and then down through the nodes adjacent to the internal jugular vein. To meet these different situations there are two types of operations: the bilateral upper neck dissection and the complete unilateral neck dissection.

COMPLETE NECK DISSECTION

This operation is done much as described by Crile in 1906 with some modifications. Its purpose is the removal of as much of the lymph node bearing tissue on one side of the neck as possible. The area of excision extends superiorly along the upper border of the lower jaw through the tail of the parotid to the mastoid posteriorly along the border of the trapezius muscle inferiorly across the top of the clavicle and manubrium and anteriorly up along the ribbon muscles to the hyoid and then across the midline to the opposite point of the chin. The block excised contains the subcutaneous fat and fascia, the platysma and sternomastoid muscles, internal jugular vein, submaxillary gland and part of the parotid.

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carotid sheath is dissected free from the artery and the vagus and reflected upward with the muscle and vein for removal.

The supraclavicular fat is then divided from the clavicle as far back as the trapezius and inward as far as the surface of the scaleni and levator scapulae muscles. During this process it is necessary to divide the omohyoid muscle where it disappears beneath the skin flaps laterally and to divide the external jugular and some of the transverse cervical vessels just above the clavicle. When it is desired to save the 11th nerve particular care must be observed during this stage to avoid severing the lower end of it. The upper end of the omohyoid is then severed where it crosses the ribon muscles anteriorly and the whole block containing the sternomastoid muscle, internal jugular vein and contents of the supraclavicular fossa is reflected upward (Fig. 6). From this point onward an assistant maintains gentle traction upward on the block to be removed.

The dissection is then continued upward on the surface of the scaleni, levator scapulae and ribon muscles and the carotid sheath is stripped from the artery and the vagus nerve to the level of the hyoid bone.¹ Care is taken to identify the phrenic and 11th nerves and save them though it is necessary to cut the sensory nerves emanating from the cervical plexus in the area. When the branch of the 11th nerve supplying the sternomastoid muscle is reached it is cut to avoid pulling up the main trunk with the block (Figs. 7, 8). The superior thyroid veins and other smaller tributaries of the internal jugular vein are divided and carefully ligated as they are reached.

When the hyoid level is reached the incision through the subcutaneous fat and fascia is carried forward just above the hyoid and then upward to the opposite side of the chin. The digastric tendon is identified as a shining white structure between the submaxillary gland and the hyoid bone attached to the upper surface of the latter (Fig. 7). The stylohyoid muscle is located alongside the posterior belly of the digastric, and subjacent to them is the 12th nerve. With care to avoid cutting

the 12th nerve, the digastric and stylohyoid tendons are both cut loose from the hyoid bone and the digastric tendon is divided. The common facial vein is divided and ligated close to the jugular and these maneuvers free the upper end of the internal jugular allow it to be rotated up out of the neck and permit high ligation of the jugular bulb (almost up to the jugular foramen) and the cleaning out of the upper carotid sheath.²

The facial artery usually presents under the posterior belly of the digastric and is then ligated and divided as is the occipital artery. Positive control of these vessels is necessary for success of the operation. Secondary hemorrhage should not occur from them but if it does it is apt to be fatal. An assistant then continues to rotate the block up out of the neck and the dissection is continued upward.



Fig. 3. Incisions for complete unilateral dissection. The horizontal (Kocher) incision extends from the mastoid to the opposite side of the chin, passing 3 centimeters below the angle of the jaw. The vertical incision extends from the middle of it down over the clavicular insertion of the sternomastoid.

¹There may be a transitory drop in the blood pressure just after the sheath is removed from the region of the bifurcation.

²The advantages of sectioning and removing the digastric and stylohyoid muscles have been well described in the French literature, notably by Dancand, Fabre and Gossy.

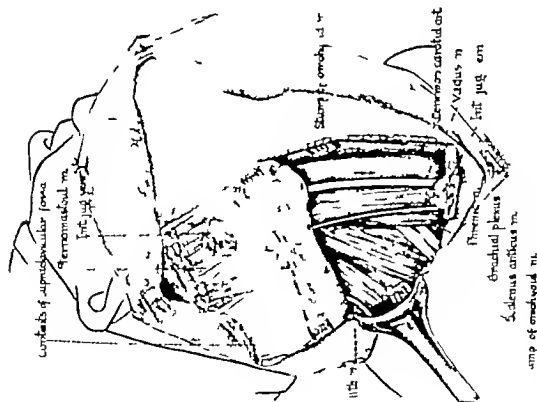


Fig. 6 The internal jugular vein is ligated and divided just above the clavicle (after which procedure the lower end usually disappears down behind the clavicle). Fat, connective tissue, and lymphatics are dissected up out of the suprascapular fossa in one block, severing the external jugular vein and several transverse cervical vessels in the process. The omohyoid muscle is cut at the lateral and medial borders of the wound. The carotid sheath is stripped from the artery and the vagus nerve and reflected upward with the jugular. Brachial plexus, phrenic, and 11th nerves are seen and protected.

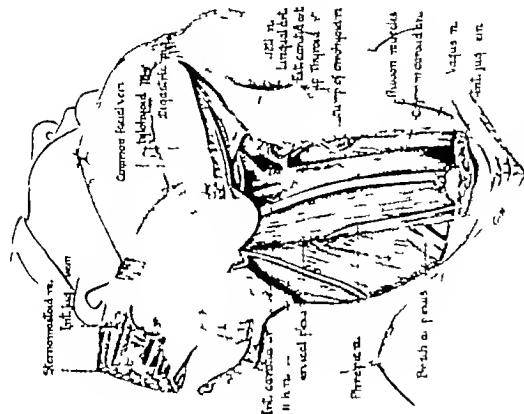


Fig. 7 Dissection is continued upward, leaving the muscles quite clean and reflecting the carotid sheath up with the block. At the hyoid level, the incision through the subcutaneous fat and fascia is carried forward to the midline and then upward to the opposite side of the chin (exposing more of the subcutaneous area than is shown on these drawings). The digastric and stylohyoid tendons are seen just above the hyoid and the 11th nerve is found crossing the carotids at the same level, and is protected. The 11th nerve branch to the sternomastoid is seen.

on the surface of the same muscles posteriorly and on the mylohyoid muscle anteriorly (Fig 9). The submental area is cleaned out completely down to the muscles; if necessary the anterior belly of the digastric is included. This tissue is left attached to the main mass along the border of the jaw and the periosteum of the lower one-third of the jaw is included if advisable because of location of the growth. The submaxillary gland is rotated up out of its fossa to the outside of the lower jaw and the chorda tympani branch is cut to free it from the lingual nerve.¹ The submaxillary duct is then ligated and cut at the point where it pierces the mylohyoid muscle. The internal jugular hulk is triply ligated as high as possible and divided so that two ties remain on the upper end (Fig 10).

The sternomastoid and digastric muscles are detached from the mastoid and the entire block is then cut loose at the upper end. The line of division runs through the tail of the parotid and along the body of the lower jaw. The anterior facial vein and facial artery as well as several large vessels which are always present in the parotid are identified and ligated on the cheek (Fig 11).

If the maneuver of cutting the digastric and stylohyoid has been followed the resected mass will be in one piece shaped somewhat like an inverted 'L' with the involved nodes deep inside of it. It is thought that this technique is definitely preferable to the one in which the lower and upper neck masses are removed in two pieces with the incision between them located in the worst place possible as far as exposure and contamination of the growth are concerned.

The lower branch of the 7th nerve is not usually saved but it can be by raising the platysma and parotid with the original upper skin flap. This is definitely not advisable in lip cancers and in most other instances but can be done when the primary lesion is in the tongue and there are no enlarged nodes near the parotid.

The entire bed is then made dry and the wound may be irrigated with saline to wash out any loose particles of fat. Sulfonamide

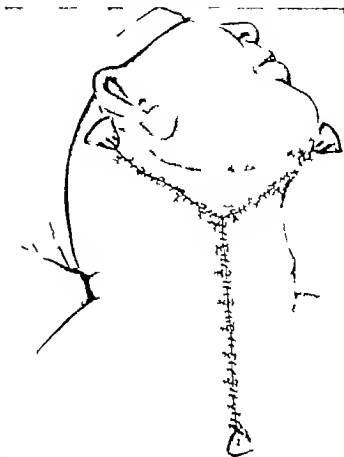


Fig. 12. Wound irrigated and flaps closed. A rubber dam drain is put through the mastoid angle to the parotid area, and another through the chin angle to the submaxillary fossa. A third drain is put up through the clavicular angle to the carotid bifurcation. After this, a large, firm pressure dressing is applied to eliminate dead spaces, prevent fluid accumulations, and to encourage early sealing down of the flaps.

powder may be lightly sprinkled over the surface if desired and the wounds are closed with a light rubber dam drain coming out of each of the three angles (Fig 12). A large cotton waste pressure dressing is applied carefully as it is thought to be an essential for successful healing both for comfort and for prevention of infection by eliminating dead spaces and fluid accumulations.

The endotracheal tube is removed and a Magill nasal airway tube is inserted so that its end is suspended just above the glottis. Both mouth and nasal suction may be used to keep the throat clean and the airways patent while the patient is awakening. Parenteral fluids may be necessary for a day or two and large doses of morphine or other respiratory depressants are avoided. The postoperative course

¹If too much traction is made on the gland, the lingual may be paralyzed with an annoying numbness of the tongue.

and mylohyoid muscles and the mass is rotated up and out of the neck to the surface of the lower jaw (Fig. 14). The submaxillary gland is freed from the chorda tympani and from its duct. The entire mass is then cut free from the mastoid to the symphysis by going through the tail of the parotid and along the body of the lower jaw (Fig. 15). The anterior facial vein and facial artery are ligated where they cross the mandible and any troublesome bleeders in the parotid are stopped. The same procedure is then carried out on the other side and the entire cuff of tissue from one mastoid to the other may be removed in one piece. The wound may be irrigated and closed with one drain from each parotid region extending out each mastoid angle and another drain extending a short distance each way from the midline. The postoperative care and convalescence are about the same as for a complete neck dissection and a large cotton waste pressure dressing is just as essential for healing.

The resultant deformity is mainly noted because of the lack of 7th nerve supply to the lower lip.

SECONDARY AND COMBINED NECK DISSECTIONS

The presence of crossed metastases makes the situation more difficult. When a patient presents enlarged nodes in both the upper and lower neck on one side and also in the upper neck on the opposite side a complete unilateral dissection can be combined with an upper dissection on the other side.

Occasionally a patient who has had a complete unilateral neck dissection with or without an upper dissection on the opposite side may later develop enlarged nodes in the lower neck on the opposite side. Complete dissections have been done on the other side in a few such patients several months after the original operation. It is noteworthy that the venous return from the brain following bilateral complete dissection must be entirely through the vertebral veins as both anterior both external and both internal jugular veins are divided in the operations. The only postoperative death in this small group was from a subdural

¹ Many of the metastatic masses are near the mandible; the perosteum is split and removed with the specimen.

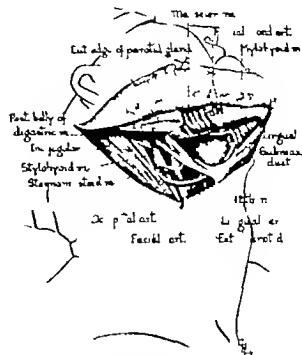


Fig. 15. After the submaxillary gland has been freed from its duct and the lingual nerve (chorda tympani branch) the block is removed by going forward from the mastoid through the tail of the parotid and along the body of the lower jaw. The perosteum from the lower $\frac{1}{2}$ of the jaw can be included with the block if advisable. The block may be left attached in the midline while the dissection is being done on the other side so that it may be removed as a single cuff of tissue extending from one mastoid to the other. After the dissection is complete the wound is irrigated and the upper skin flap is sutured down in place. One drain is placed in each mastoid angle, and a double one in the midline anteriorly extending to each submaxillary fossa. A large firm pressure dressing is again necessary for good, quick healing.

hematoma in a young woman, a factor indicating that the intracranial venous pressure must be raised considerably. Older patients have shown no eye ground changes or other evidences of increased pressure but it is possible that the rate of arterial flow to the brain has been less in them.

At times enlarged nodes may appear in the lower neck on one side in a patient who has had a bilateral upper dissection. A complete dissection can then be done beginning at the clavicle and including the removal of the sternomastoid muscle, internal jugular vein and carotid sheath without the necessity of re-entering the submaxillary triangle.

The combination of neck dissections with extensive mouth operations is avoided if possible. Many primary lesions of the tongue

floor of the mouth, fauces, and buccal mucosa can be treated with interstitial radon seeds satisfactorily when early and if there is no involvement of bone. However in alveolar carcinomas or any others in which the bone is involved by extension radical cauterization operations are done usually with a neck dissection on the same side. Care is taken in the dressings to try to prevent the drainage of saliva down into the neck in so far as possible.

The combination of neck dissections and extensive mouth operations carries a higher mortality and secondary neck dissections carry a somewhat higher mortality and poorer ultimate prognosis. However when necessary and when there are no contraindications each may salvage patients with an otherwise hopeless prognosis.

When any of the neck nodes are fixed or inoperable or in other unusual circumstances interstitial implantation of radon seeds into the nodes and surrounding tissues can be done. They may be introduced preferably under direct surgical exposure or blindly through the skin. External radiation can be used in inoperable cases for temporary respite without much hope of ultimate cure.

MORE RADICAL NECK DISSECTIONS

Metastatic involvements of the neck requiring more radical procedures than those here described are usually classed as inoperable and treated as such but with occasional exceptions. Overlying involved skin segments have often been resected with the block. The common external, and internal carotid arteries were removed in one patient who had a mass

completely surrounding the bifurcation and he has remained well without recurrence for 4 years. There were no complications but examination of the specimen showed that the tumor had compressed the common carotid and it is well known that sudden ligation of the common or internal carotid may be followed by death or hemiplegia. One vagus nerve can be removed without apparent serious cardiac or pulmonary sequelae, but with unilateral vocal cord paralysis and consequent danger to the laryngeal airway. Removal of the 11th and 12th nerves results in a shoulder drop and thick indistinct speech, respectively and the results of phrenic excisions are well known.

SUMMARY

Radical neck dissections for metastatic carcinoma offer the best chance for cure in many instances, provided the original lesion can be controlled. While anyone would like to avoid such procedures the technique of the operation should be preserved for the present at least, in the therapy of carcinoma.

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MALIGNANT TUMORS ARISING FROM THE SYNOVIAL MEMBRANE WITH REPORT OF FOUR CASES

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THERE is increasing interest in malignant tumors arising from the synovial membrane although they are fairly uncommon. Little attention was paid to these tumors until the first part of the present century. The first work of importance on this group in this country was by L. W. Smith in 1927, who reported 3 cases of such tumors. The next important contribution on this group was by Knox who reported 3 cases in 1934 (8) and reviewed the literature in 1936 (7). Coley and Pierson, Berger, Briggs and DeSanto and associates, reported other cases and contributed toward a better understanding of this group of tumors. The most recent review of the subject was by Lazarus and Marks who collected the 74 previously reported cases and added 2 of their own. They did not include the 2 cases reported by Fisher in 1942. The 4 cases being reported here bring the total number of such tumors which have been reported up to 82.

Various names have been applied to this group of tumors including synovioma, synovial sarcoma, spindle cell sarcoma, perithelioma, villous angiofibroma, synovial sarcoendothelioma, myxosarcoma and synovial sarcomesothelioma.

Synovial tissue is encountered in the synovial membranes of joints, serous bursae and tendon sheaths. It is generally agreed that synovial tissue arises from mesodermal tissue. Sabrazès conceives of it as being reticuloendothelial tissue while Berger favors the conception that it is a tissue *sui generis* being a part of the reticuloendothelial system in a broad sense. Since there is disagreement as to the origin of the synovial tissue there is confusion about the proper nomenclature. The term malignant synovioma seems fitting and very useful from the clinical standpoint

since it does have anatomical significance and would separate this group of tumors from the benign tumors arising in the same locations.

These tumors occur most frequently in subjects between 20 and 40 years of age, the youngest patient being 9 months old and the oldest patient being 75 years of age. About half occur about the knee joint. Other areas commonly involved are the elbow, ankle, foot, thigh and palm of hand. One of the cases being reported here occurred in the upper arm, the first such case reported occurring in this region. Both sexes are about equally affected, 42 cases having been reported in males and 39 cases in females.

Trauma has been reported in an appreciable percentage of these patients as having preceded the tumor, but the relationship of trauma to the tumor growth is thought to be not more than incidental. They have been reported as occurring in areas which have previously been the site of chronic bursitis or synovitis. In about half of the patients pain is a prominent symptom and in about one third of the patients pain is the initial symptom. About 95 per cent of the patients have a noticeable tumor mass which is frequently tender. In some cases the swelling had been present for from 6 to 10 years before operation, while in others the tumor mass had been present for only a few months. The original rate of growth is commonly very slow.

Grossly the tumors may be firm or soft. Some are well circumscribed and others are poorly delimited from the surrounding tissue. They are usually grayish white in cross section but may be reddish or bluish. They are usually very vascular and many contain small clefts and cystic areas which frequently are filled with clear viscid material.

Microscopically these tumors are differentiated into two types. The first type apparently arises from the outer, more dense layers of the synovial tissue and is usually

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Fig. 2. Case . . . Photograph of the gross specimen after removal and partial dissection. The tumor, as it occurs in the region of the palm of the hand.

is indistinguishable from the common fibrosarcoma. The second type seems to arise more from the inner layer of the synovial tissue and is more epithelioid in character. It is the type which Fisher reports as synovial sarcoma-endothelioma. A characteristic feature of this second type is the presence of clefts or spaces lined by cuboidal or polyhedral cells often resembling pavement epithelium. These clefts are scattered about between closely packed spindle-shaped or ovoid cells. All of the 4 cases reported here are of the second type. It is probable that there have been cases in this clinic of the former type which were simply called fibrosarcoma. Briggs believes this to be the case in the series he reported.

The prognosis is very unfavorable. In the cases reviewed by Lazarus and Marks, 56.6 per cent developed recurrence and metastases promptly and only 16 per cent of the 64 cases

with follow ups were living 5 years or more after operation. In this same group 25 per cent died within the first year. The data are still insufficient for a correlation between the prognosis and the length of time the tumor had been present before operation. Several writers have suggested that those tumors consisting of closely packed cells with oval or round nuclei are more malignant than those with many multinucleated giant cells. Those containing well defined cleft-like spaces are thought to be intermediate in malignancy. Death is generally due to pulmonary metastases although cerebral metastases occur occasionally.

DeSanto and associates recommend wide local excision for encapsulated and accessible tumors with subsequent radical amputation if sections indicate a high degree of malignancy or if recurrence follows. They recommend immediate radical amputation in all diffuse and inaccessible tumors, such as occur about the knee joint. Berger agrees with Sabrazès that immediate high amputation of the affected extremity is indicated since one frequently is forced to amputate later for recurrence. At the time of the subsequent amputation it is usually too late. Briggs agrees in general with the treatment as outlined above by DeSanto and associates. Irving suggests that diagnosis should be made by aspiration and that the tumor be treated by external radiation to the limit of skin tolerance followed by interstitial radium. He reserves resection and amputation as the last resort. However, proof is lacking that irradiation is beneficial. Our own cases are insufficient to warrant any conclusions regarding the best method of treatment. However, we have tended to follow the more conservative method of treatment. One of the difficulties encountered in treating these patients is that before operation the diagnosis is seldom suspected and never certain. The diagnosis may be suspected from the location and gross examination of the tumor but can be made only from the microscopic sections. The surgeon probably is not as radical in his excision of the tumor as he would be if he knew beforehand the diagnosis. If there is any doubt as to the completion of the excision at the original

operation he should perform a really wide excision of the area without delay. Study of frozen sections of the tumor at time of removal may give enough information to one familiar with this group of tumors to enable the surgeon to continue with the more radical excision of the area at the first operation or if inaccessible to proceed with the amputation of the involved extremity. A radical local excision originally should decrease the chance of recurrence significantly. If for any reason this is not feasible or if there is recurrence then amputation must be performed.

Lewis reviewed the 16 cases reported by DeSanto and associates from the standpoint of the radiographic appearance of the tumor. Thirteen of these cases had x ray pictures taken. A characteristic roentgenograph was present in 4 of these cases and he concluded that a provisional diagnosis of synovoma could be made in about 25 per cent of these tumors. He points out that a rounded some times lobulated sharply defined soft tissue tumor mass is seen which in itself is not diagnostic. But he adds when there is scattered and irregular deposit of amorphous lime in the mass a provisional diagnosis of synovoma is justified.

It is our purpose in this paper again to call to the attention of surgeons this group of highly malignant tumors which have to be treated with great respect and to report 4 additional cases of such tumors. These cases are presented in some detail since in some of the previously reported cases there has been criticism of the lack of detailed information given in the case reports.

CASE REPORTS

CASE 1. S.L. No. 159673 a 60 year old Italian woman entered the Rochester Municipal Hospital on November 24, 1939. Three and one half years before entry she first noted some tenderness and a small swelling on the dorsum of the 4th right metacarpal bone. This grew to about the size of a walnut and was removed surgically elsewhere. The diagnosis of spindle cell sarcoma was made and the patient received both x ray and radium therapy at varying intervals following the operation. She got along quite well with only occasional pain in that hand until about 6 months before her entry here when she first noted a small black spot on the palmar surface of the same hand. This grew continuously and was quite painful particularly at night. During



Fig. 1. Case. Low power (X38) and high power (X370) photomicrographs of the microscopic sections made from the tumor. These show clearly the clefts which are a prominent feature and the 2 distinct types of cells of which this tumor is composed.

the 2 weeks preceding her admission here the mass became ulcerated and bled on several occasions. No history of trauma was obtained. The past history was noncontributory except for hypertension for at least 3 years.

Examination on admission revealed a well developed and well nourished woman appearing clinically ill. Her blood pressure was 195/90, her pulse was 85, and her temperature was 36.5 degrees C. A systolic murmur was heard at the apex and was transmitted to the axilla. The area of cardiac dullness was somewhat increased. On the palmar aspect of the right hand overlying the 3d, 4th, and 5th metacarpals there was a dark reddish brown firm but friable mass with a broad base. The mass measured about 4 by 4 by 4 centimeters and was partially covered by dried blood. Scar tissue was present over the dorsum of the hand and this region

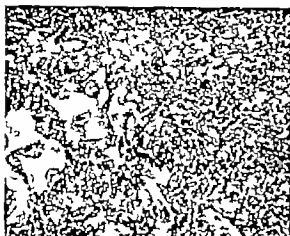


Fig. 3. Case . . . Low power ($\times 38$) and high power ($\times 170$) photomicrographs of the microscopic sections made from the tumor. The clefts are less prominent in these sections than in Case . . . Some of the clefts are filled with amorphous substance, as seen in the low power photomicrograph. Two types of cells are seen here also, but less distinctly than in Case . . .

was quite firm. There was diffuse thickening of the entire right hand. There were palpably enlarged regional lymph nodes but there was a small firm node beneath each ear. The physical examination was otherwise essentially negative. A chest plate showed some enlargement of the heart but the left but showed no evidence of metastases to the lungs. X-ray film of the hand showed some generalized decalcification with almost complete destruction of the 4th metacarpal and partial destruction of the 5th metacarpal bone. Under nitrous oxide-oxygen and ether anesthesia, the hand was amputated 4 centimeters proximal to the wrist joint. There was an uneventful convalescence. A photograph of the gross specimen is shown in Figure . . . As the specimen was saved for a gross specimen, it was not com-

pletely dissected and its extent toward the dorsal surface is not known. It did seem to be invading between the fascial and muscle layers. The cut surface of the tumor was soft and grayish white with a solid fibrous appearance.

Microscopically the tumor mass is poorly encapsulated and in some areas is poorly delimited from the surrounding connective tissue. There are strands of dense connective tissue which extend down into the tumor tissue and tend to separate the tumor tissue into lobules. Most of the tumor is composed of spindle shaped cells many of which have slender protoplasmic processes extending from the ends of the cells. The tissue seems to be growing quite slowly and irregularly but no definite mitotic figures are seen. A second distinct type of cell is seen. These cells are polygonal and darkly stained. They have larger nuclei which are darkly stained and tend to be more round or oval in shape. These cells are arranged in single or few rows about the many small and moderately large clefts which are scattered about within the tumor. The nuclei of the spindle shaped cells are more ovoid and narrow and less darkly stained than the nuclei of the polygonal cells. Some of the clefts which are seen appear to have been much larger at one time and to have been filled partially by papillary outgrowths of tumor tissue into the clefts. Focal areas of necrosis are seen. One section shows the tumor to be spreading between the flexor and adductor muscles of the 5th finger. Figure 3 shows a high and a low power photomicrograph of this tumor.

The patient was discharged from the hospital on December 9, 1936, and was last seen here on April 17, 1940 at which time she was completely healed, asymptomatic, and showed no evidence of local recurrence or metastases. Personal communication with her local doctor revealed that the patient died "few weeks" later with cardiac failure. At the time of her death, her local doctor reports that there were a few palpable lymph nodes in the axillae but that, as well as he could determine, there was no evidence of metastases to the lungs or elsewhere. No autopsy was obtained.

CASE 2. A. W. No. 125. 8, a 5 year old married woman, entered the Strong Memorial Hospital on March 31, 1937, with the history of having had a small lump on the anterior surface of the left upper arm for several years (215). She desired its removal because it had recently become tender. There was no recent increase in size or discharge from the lump. Examination showed a cherry-sized, fluctuant and slightly tender nodule just beneath the skin on the anterior aspect of the left upper arm. Before operation it was thought to be a sebaceous cyst. Under local anesthesia the tumor was excised, no mention being made of its being connected to the muscle fascia, or tendons in this region. The tumor measured 8 millimeters in diameter appeared to be encapsulated, and was firm and yellowish gray. The central part of the tumor was cystic and cellular while about the periphery there were small islets of

yellow tissue which appeared xanthomatous. A 3 millimeter long pedicle like structure was present on one end of the tumor.

Microscopically the tumor is not well encapsulated although it is sharply delimited from the surrounding connective tissue. It is composed of small and large masses of tumor cells many of which are arranged as cords of cells and others of which are papillary in arrangement. Some of the papillary projections extend into cleft-like spaces which are intermingled one with the other. Between many of these groups of tumor cells there is mucoid connective tissue and a few areas of dense connective tissue. Some of the clefts are filled with the mucoid substance, others are empty and still others contain a colloid like substance. The cords and papillary projections of tumor tissue are composed of large and small cells with small dark nuclei and with large pale vesicular nuclei which are oval round or irregularly shaped. The cell outlines are very indistinct, but some cells are suggestive of spindle cells while the cells about the periphery of the clefts are mostly smaller and more cuboidal. Mitoses are frequent (see Fig. 3).

The patient was last seen here 6 days after the removal of the tumor, April 12, 1937, at which time the wound was well healed. Nothing is known regarding her later course except that she died at home about 5 months later on August 23, 1937.

CASE 3. F. A. No. 201373, a 65 year old married woman was admitted to the Strong Memorial Hospital on February 22, 1943. Three years before entry she had fallen on her left knee causing a mild contusion. She suffered no other complaints in this region until 6 months later when she noted a small lump in this region which was neither discolored nor tender. This did not change noticeably until 7 months before her entry here when she again fell upon her left knee. Since this fall, the lump has been discolored and has become more nodular. There was a prickling sensation at times in this region but the mass was not tender nor painful. She noted no difficulty in walking. Examination of the patient revealed nothing of significance except for the local examination. No enlargement of the regional lymph nodes was found. Immediately below the left patella on the anterior aspect of the knee there was a 3 centimeter in diameter irregularly shaped firm nodular mass. This was bluish and it seemed to be attached to the skin. It did not move freely over the underlying tissues. An x-ray examination of the chest showed no evidence of metastases. The laboratory findings were within normal limits. On the day following admission a local excision of the tumor with a fairly good margin of surrounding tissue was carried out, under general anesthesia. The dissection extended down to the fascia overlying the lateral muscles and to the patellar tendon and to the tibia. The tumor was composed of many solid and cystic nodular areas extending over an area of about 5 by 5 by 3 centimeters. In the center of the mass there was a 2

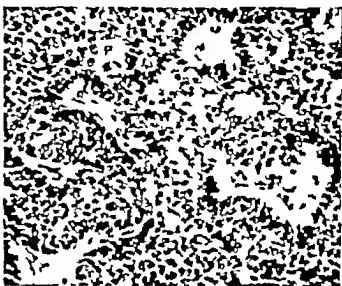
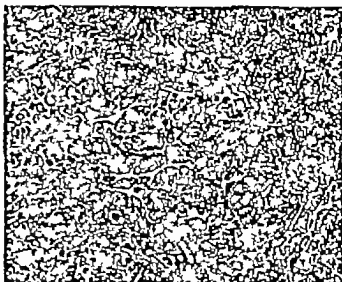


Fig. 4. Case 3. These low power ($\times 38$) and high power ($\times 370$) photomicrographs show clearly the papillary arrangement of tumor cells with the cleft-like spaces scattered throughout the sections. The high power photomicrograph demonstrates the rosette like appearance caused by the cleft-like spaces being bordered by cuboidal to columnar cells.

centimeter in diameter cystic area which at operation was filled with coffee ground like semifluid substance. The solid nodules were grayish yellow and cellular in appearance and quite firm in consistency.

Microscopically the tumor was composed of lobulated masses of tumor cells. The lobules of tumor tissue were poorly encapsulated, but they were sharply delimited from the surrounding dense connective tissue. There were large and small cystic areas filled with colloid-like material some of which contained cholesterol clefts. Some of the cystic areas were filled with fresh hemorrhage and still others were filled with cellular debris. Smaller clefts were seen scattered about the tumor tissue

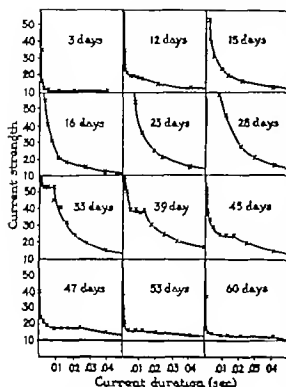


Fig. 1. After Adrian.

to the point of incidence of the stimulus shifting from nerve to muscle. He also noted that the beta curve (attributable to the myoneural junction) is not obtained after denervation. Furthermore, the curves illustrating his article show no other discontinuity when the muscle was denervated.

We may now return to the work of Adrian. He showed that when in the human the nerve degenerates, the chronaxie falls from 0.003 to 0.015 second, in a case of sciatic nerve section and from 0.0024 to 0.010 second in a case of facial palsy. In studying the manner in which the rapid curve is transformed into the slow one he showed that soon after a facial palsy and in cases of anterior poliomyelitis, with incomplete paralysis, the strength duration curves were complex. They are made up of a steep sharply bent curve when the current strength is high and the duration short and a slower and more gradual curve when the duration is longer and the strength less. The time constants of these two components of the curve are found to agree very closely with the average values for muscle with intact and with degenerated nerve supply."

He then concludes that there is no gradual transition from the rapid to the slow curve as the nerve degenerates. Instead of this, we have a period in which both curves are found together and the transition consists in one curve becoming more and more prominent to the ultimate exclusion of the other. This he beautifully illustrates by duration strength curves in a case of facial palsy from the 3d to the 60th day after paralysis. On the 12th day a double curve is obtained, the discontinuity occurring when the voltage strength is 20 times the rheobase value. On the 15th day the rapid curve has been almost entirely replaced by the slow, but it is still possible to detect a break in the curve at a voltage strength of 55 times the rheobase value and, with greater strength than this, the curve is of the rapid type. On the 16th day no discontinuity can be found and the curve is of the slow type throughout. At the 33d day the rapid curve reappears at a voltage strength of 50 times the rheobase value—after the 33d day the rapid part of the curve appears at weaker and weaker voltage strengths and eventually it completely re-

onstrated in a strength duration curve it showed a kink (called discontinuity by Adrian). It consisted of gamma at short durations and alpha at long durations. He also showed that when condenser discharges are used as stimuli the strength capacity curves also showed alpha and gamma portions, but the kinks are generally not so obvious as in the case of brief constant currents (14). It should follow that when nerve fibers are completely degenerated gamma excitability could not be shown in a strength duration curve, no matter what the size of the electrode would be.

Watts, in studying strength duration curves of the denervated muscles of the frog, found that the alpha curve remains practically the same throughout the muscle during degeneration of the nerve but does not insist that the "chronaxie" of the muscle remains absolutely unchanged, after degeneration of its nerve. Thus, he says, "The great increase in the chronaxie observed in human subjects after denervation is due not to any alteration in the time constants of the muscle fibers, but merely

places the slow curve about 60 days after on set of the paralysis (Fig 1). The appearance of the rapid curve antedated a diminution of the chronaxie of the slow curve by 12 days. He explained the observations as follows:

"When the nerve is intact the current which is just strong enough to cause contraction takes effect on the rapid mechanism alone as the nerve degenerates, the rapid mechanism needs stronger and stronger currents to excite it and at weak strengths and long duration the slow mechanism comes into play. Eventually the rapid mechanism becomes completely inexcitable and the current takes effect on the slow mechanism alone." With regeneration the process is reversed. He identified the rapid mechanism with the nerve fiber and the slow mechanism with the muscle fiber.

Having thus beautifully demonstrated a method for discovering the persistence of functional nerve fibers during the early part of degeneration and their recovery throughout regeneration, he nevertheless concluded that little was to be gained by the use of such elaborate methods in electrodiagnosis. He was led to this conclusion as he believed that presence or absence of excitable nerve fibers could be detected by ordinary faradic coil.

"When the nerve has degenerated the faradic current becomes ineffective since it is too rapid to excite the muscle fibers. As soon as this state of affairs is reached electrical methods cease to give any indication of the condition of the nerve at the seat of injury."

This conclusion we believe to be fallacious. First in the experimental animal (the cat) excitation by faradic stimulation persists throughout the period of denervation and regeneration both when the stimulus is applied percutaneously and on the exposed muscle. In man exposed muscle continues to contract when stimulated by faradic current and if the necessary strength of current were bearable it probably would produce and has been found to produce contractions percutaneously. Second many cases show motor recovery long before percutaneous faradic stimulation produces contraction. Third in spontaneously recovering lesions destined to recover in a period of time less than that which would be required were the part of the nerve distal to



Fig 1. Oscillogram of the constant current impulse of 0.005 second duration.

the injury completely degenerated failure to respond to faradic stimulus is common.

METHOD

Various devices have been used to produce stimuli of variable short durations. Some have been mechanical devices to close and open a circuit carrying direct current. Among these may be mentioned Keith Lucas pendulum and spring rheotome, Lapicque's (10) chronaximeter and Sachs and Malone's (15) chronomyometer.

More frequently, the variations in time necessary for the discharge of condensers of varying capacitance through resistance circuits have been used to limit the time of stimulus.

Finally electronic devices delivering square waves of direct current of variable durations have been used (Bouwens).

The objections to the use of mechanically interrupted direct currents are (1) they are not accurately timed (2) the contacts are not always certain in operation (3) changes in tissue impedance and the presence of capacitive or inductive reactance preclude the possibility of obtaining true square waves (truly constant current impulses) and (4) it is not possible to measure accurately the magnitude of the current which flows.

The objections to the use of condenser discharges are (1) that the current is sustained but for a fraction of the time necessary to dis-

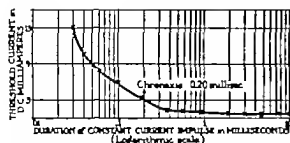


Fig. 3. Strength-duration curve of the gastrocnemius muscle in the normal cat.

charge and (2) that in most circuits usually conforming to Bourguignon's circuit the amperage through the tissues cannot be measured.

By the use of various types of vacuum tubes in circuits it is possible to maintain a constant flow of current regardless of the variations of voltage across the tissue or to put it differently there can be provided a current of rectangular wave shape irrespective of the nature of the electrical impedance of the tissue to which the current is applied.

In a high vacuum pentode the emission of electrons is produced by heating the cathode. The flow of these electrons from the cathode to the plate is controlled by the operating voltages which are applied to the various grids within the pentode. As long as the voltage applied to the plate is kept above a certain minimum the plate current is practically independent of the plate voltage.

The latter fact permits the tube to send through a circuit containing changeable impedance such as biological tissue, a definite predetermined constant unidirectional current. The impedance may contain capacitance or changeable resistance which can vary from 0 to 10,000 ohms without changing the value of the current which is being sent through the circuit.

It should be clearly stated that the phenomenon of polarization has absolutely no effect on the predetermined and readily controllable value of current which is passed from the plate of the pentode tube through the specimen.

In 1936 Conrad, Haggard and Teare described an apparatus for producing a current of rectangular wave shape the intensity and

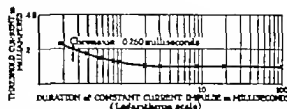


Fig. 4. Strength-duration curve of the flexor sublimis digitorum in normal man.

duration of which could be accurately controlled and measured.

The duration of the impulse was controlled by two gas-filled triodes, one of which served to initiate the flow of current while the second served to stop it. A constant flow of current through the tissue was maintained by a pentode operated on the saturated portion of its characteristic.

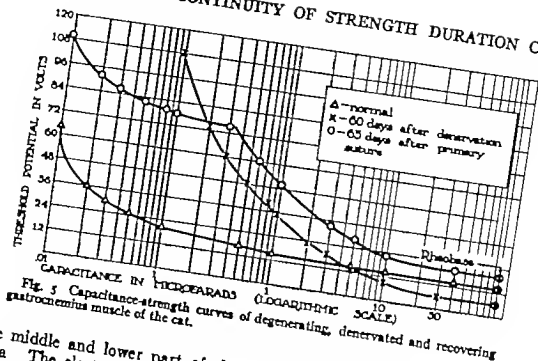
METHOD

For this study an apparatus was devised (7) which in principle is similar to the one described by Conrad, Haggard, and Teare but which differs in that it is entirely alternating current operated. It has the further advantage of permitting us to reproduce the wave form irrespective of the time interval between stimuli. With this apparatus we are able to obtain an impulse of rectangular wave shape lasting for as short an interval as 30 microseconds (Fig. 2). Thirty-three different time intervals, selected to conform to a logarithmic scale were made available. They ranged from periods as long as 2 seconds to one as short as 30 microseconds.

The material consisted of cats in which a section and immediate suture of the sciatic or peroneal nerve was done and animals in which after a long segment of the sciatic nerve was removed the proximal stump was injected with alcohol to discourage regeneration.

Before the examination the site over which the electrodes were to be placed was vigorously rubbed with electrode jelly to minimize cutaneous resistance. The indifferent electrode measuring 2 centimeters in diameter was placed over the lateral portion of the Achilles tendon. The exploring electrode the cathode measuring 1.5 centimeters in diameter was

POLLOCK ET AL. DISCONTINUITY OF STRENGTH DURATION CURVES



placed in the middle and lower part of the popliteal fossa. The electrodes which were circular were constructed of copper and covered with chamois. They were immersed in salt solution for 15 minutes prior to use and then covered with electrode jelly.

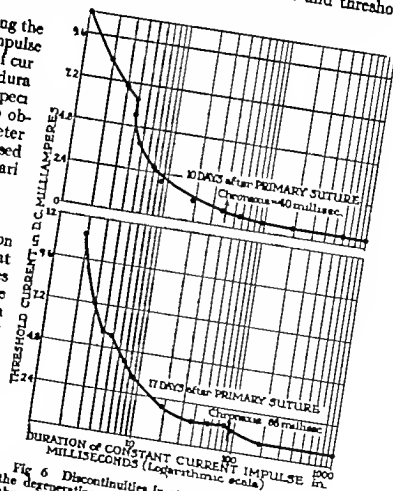
The rheobase was determined by finding the threshold value of current when the impulse lasted 1 second. Then threshold values of current were found for successively shorter durations of the impulse. By shunting the specimen out of the circuit it was possible to observe the amperage in a suitable millimeter as much time as was necessary being used as painful unbearable stimuli and severe polarization changes being avoided.

RESULTS

Since we will describe strength-duration curves from data obtained both from the cat and man, we wish first to illustrate such curves from the normal gastrocnemius muscle in the cat and the flexor sublimus digitorum in man (Figs 3 and 4). In both instances the curve is a continuous one. In the case of the cat the chronaxie was 0.00014 second in the case of man 0.00021 second.

The changes from normal of strength-duration curves during degeneration, denervation and regeneration consist of (1) changes in threshold current at various durations, (2) changes in chronaxies and (3) discontinuities in the curve.

In this study attention is directed especially to the discontinuities and some reference only will be made to the chronaxie and threshold current.



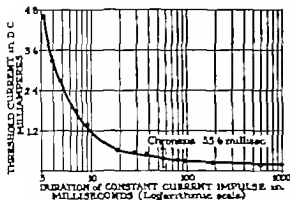


Fig. 7. Strength-duration curve of the gastrocnemius muscle of the cat, 60 days after denervation.

After section of a nerve as degeneration progresses, at first threshold amperage increases at all durations relatively less at durations longer than 0.010 second and very steeply for those of shorter durations.

When the muscle is denervated the threshold amperage for durations shorter than 0.030 second is even larger but for longer durations, the threshold amperage is less than in the normal. As regeneration begins and progresses the threshold amperage diminishes more markedly at the shorter durations than at the longer ones. This is illustrated in a graph derived from data obtained from examinations by condenser discharges, showing the voltage-capacitance curves of the normal denervated and recovering gastrocnemius muscle (Fig. 5).

The changes in chronaxie have been amply described in the literature and we will refer only to such changes as may relate to our discussion of discontinuities in the curve.

During the state of degeneration from the earliest date after section and suture at which we have examined animals (6 days) discontinuity in the curve can be demonstrated. At times several discontinuities, usually 3 (Fig. 6a) at times but 2 (Fig. 6b) may be seen.

During the period when the muscle is completely denervated the curve is continuous, as may be seen in the curve illustrated by Figure 7 obtained from a gastrocnemius muscle 160 days after denervation.

When regeneration has progressed to the point of neurotization of muscle discontinuities again appear as may be shown in the

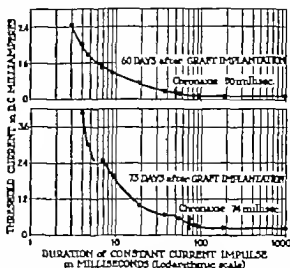


Fig. 8. The change from the continuous strength-duration curve during the state of denervation, a, above, to discontinuous one at recovery b, after nerve graft in the cat.

change from a continuous curve during the denervated state of a muscle 60 days after a homogenous graft 4 centimeters long had been placed between the proximal and distal ends of a sciatic nerve (Fig. 8a) to a discontinuous one 13 days later (Fig. 8b). The chronaxie was longer at the 73d day where the discontinuity of the curve indicated recovery (0.074 sec.) than at the 60th day (0.030 sec.). That recovery was occurring was confirmed by examination by progressive currents of long duration. Such discontinuities are even more apparent in man. This is well illustrated by the strength duration curves of 3 cases of paralysis of the 7th nerve (Fig. 9 a b c). Figure 9c represents the graph from data obtained from a patient who has the slightest return of active motion 1 year after a gunshot wound in the other two no motion has been observed. In one (Fig. 9b) the recovery is beginning too soon after onset 42 days, for the lesion to have been complete.

During denervation the curve is continuous as is the case in Figure 10a, illustrating the strength-duration curve in a man who sustained a gunshot wound of the peroneal nerve 48 days prior to examination. The lesion, however, was spontaneously recoverable and a discontinuous curve appears at the 55th day

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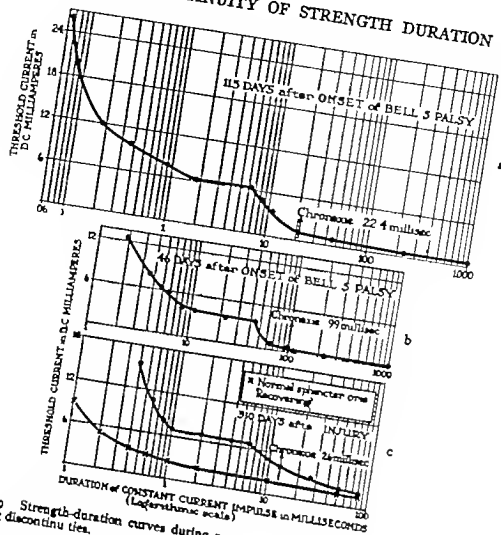


Fig 9. Strength-duration curves during recovery from facial palsy in man, showing discontinuities.

after the injury (Fig 10b). The chronaxie at the 48th day when the curve was continuous was 0.040 second and when discontinuity of the curve indicated recovery at the 55th day it was 0.042 second.

With others (12) we have shown that one of the characteristics of regenerating muscle is that with progressive currents of long duration long before voluntary motion returns a greater and greater amount of current is necessary for adequate stimulus when the duration of the wave is longer and longer.

On the other hand during denervation it will require practically the same amount of current for adequate stimulus when the duration of the progressive current is 1 or 4 seconds. During the period of degeneration no great increase of current is necessary for adequate stimulus at long duration.

Combining the examination by progressive currents of long duration with strength dura-

tion curves one can tell if a muscle is degenerating or recovering. When a muscle is degenerating the strength duration curve is discontinuous but with progressive currents of long duration the threshold amperage need not be very large. On the other hand when a nerve is recovering and a discontinuous curve is present the threshold amperage is very high for stimulus by progressive currents of long duration.

Most important is the observation that when a nerve has been but partially injured sufficient to produce paralysis but not severely enough to produce Wallerian degeneration throughout the part distal to the injury the strength-duration curve is discontinuous but no great increase of amperage is necessary to produce adequate stimulus with progressive currents of long duration. Therefore when a sufficient time has elapsed after injury to a nerve to have produced the condition of de-

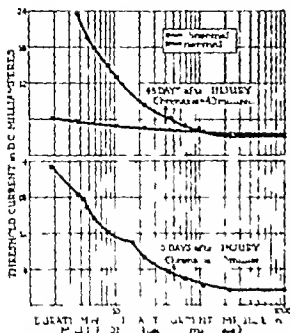


Fig. 10. The change from the continuous strength-duration curve during the state of denervation, a line to discontinuous on recovery by fiber gunshot wound of the peroneal nerve in man.

nervation were the nerve severed or severely injured and a discontinuous strength-duration curve found but no great increase of current necessary for adequate stimulus with progressive currents of long duration one may with certainty say that the nerve is but partially injured.

In Figure 11 is illustrated the strength-duration curve of a man whose peroneal nerve was injured by a stab wound 250 days before. The discontinuity of the nerve is indicative of recovery. The threshold ampereage with a progressive current of one second duration was 10 milliamperes and no contraction appeared at 22 milliamperes with a progressive current of 4 seconds duration. Contrasted to this is the case illustrated in Figure 9a of a facial palsy spontaneously recovering 100 days after onset. In this case the threshold ampereage for stimulus with progressive current of 1 second duration was 4.5 milliamperes with 1 of 4 seconds duration only 5 milliamperes. At times the threshold ampereage for currents as long as 4 seconds may be somewhat higher, 10 to 12 milliamperes but very high threshold

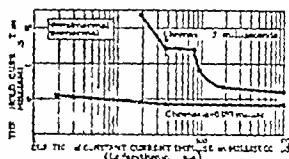


Fig. 11. Discontinuity in the strength-duration curve of the tibial nerve, 250 days after stab wound of the peroneal nerve in man.

ampereage as more than 20 milliamperes is not observed.

DISCUSSION

Although discontinuities of strength-duration curves indicative of stimulus characteristics of muscle and nerve have been demonstrated in the normal frog nerve-muscle complex by the use of large fluid electrodes they do not appear in the normal mammalian nerve muscle complex of rat or man when stimulation is effected through electrodes or dinarily employed.

We have been able to confirm Adrian's observation that during the period of degeneration before the muscle is completely denervated discontinuities in the strength-duration curve appear. Furthermore they disappear and the curve becomes a continuous one but one characteristic of the alpha portion of the curve representing the stimulus characteristic of muscle when the muscle is completely denervated. Moreover a discontinuity reappears when neurotization occurs and the stimulus characteristics of both gamma at short durations and greater strength and alpha at longer durations and lesser strength are present.

When neurotization is indicated by the re appearance of discontinuities in the strength-duration curve the chronaxie may remain unchanged from that observed when the state of complete denervation of a muscle was reflected by a continuous strength-duration curve characteristic of the alpha portion of the curve. In such cases the successful neurotization of muscle was confirmed by examina-

tion by stimuli by progressive currents of long duration

A very high threshold amperage for stimulation by progressive currents of long duration is characteristic of recovering nerve muscle complex. On the other hand although somewhat increased the threshold amperage in the case of degenerating and partial lesions is not great

When therefore a discontinuous strength-duration curve is seen and no great increase of threshold amperage for stimuli by progressive currents of long duration is necessary, provided that sufficient time has elapsed from the time of injury to have produced denervation were a nerve severely injured or sectioned then we can with certainty say that the nerve is not sectioned and is spontaneously recoverable. On the other hand if the threshold amperage for progressive currents of long duration is high we can predict that a severely injured nerve is recovering

Recently Doupe has questioned the accepted view that a kink in a strength-duration curve indicates two elements with different excitabilities. He suggests that such kinks may arise in some instances from two modes of response in the one element

Even in the normal muscle he found such a kink especially if the preparation had been cooled by immersion in water at 20 degrees Centigrade. He therefore concluded that the difference between the curves obtained from normal and from denervated muscle is more a matter of degree than of kind

As may have been seen from our data from experimental animals and men discontinuities were not observed in denervated or normal muscles. Furthermore whatever may be the final conclusion as to whether the discontinuity represents the reaction of two tissues with different excitabilities or two modes of response of one tissue discontinuities in

strength-duration curves are of diagnostic and prognostic value

CONCLUSIONS

1 Discontinuity of strength-duration curves in degenerating and regenerating nerve muscle complex have been found confirming Adrian's observation

2 During the state of denervation the strength-duration curve is continuous

3 The appearance of a discontinuity in a strength-duration curve when a continuous one indicative of denervation had formerly been present is a more accurate indication of recovery than a diminution of the chronaxie

4 By combining the results of stimulation by progressive currents of long duration with strength-duration curves one may differentiate degenerating, recovering and partial injuries

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THE USE OF RADIOACTIVE SODIUM IN STUDIES OF CIRCULATION IN PATIENTS WITH PERIPHERAL VASCULAR DISEASE

A Preliminary Report

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THE viability of an extremity is dependent upon the arterial blood which reaches it through its main arteries or through their branches which constitute the collateral circulation. Prognosis and results of therapy in peripheral vascular disease could be more accurately judged if a simple objective method were available for measuring the arterial flow through these two circulations. Most of the available physiological tests are clinically impracticable. In searching for a practical procedure it occurred to one of us (BCS) about 2 years ago that if radioactive sodium were injected intravenously at the antecubital fossa its arrival in other parts of the body could be recorded by a Geiger Mueller counter and thus circulation time from arm to any desired region obtained. Since there is constant interchange of sodium between blood plasma and extravascular fluid the amount of radioactive isotope will increase in any particular region until equilibrium is attained. This can be followed by the rate of response of the counter. The manner in which this equilibrium is built up may be related to the degree of pathological change in the vessels of the extremity.

The problem was discussed with Professor John R. Dunning of the department of physics of Columbia University and he kindly consented to provide the radioactive sodium from the cyclotron laboratory and to lend a Geiger Mueller counter for making the measurements. The authors are greatly indebted to several members of the cyclotron laboratory for their co-operation throughout the course of this work.

From the Departments of Surgery and Radiological Research, College of Physicians and Surgeons, Columbia University with the aid of a grant from the Lila Robson Hyde Foundation.

All patients investigated have had complete clinical examinations directed toward discovering the profundity of the pathological changes in their vascular systems. History and physical examination have been supplemented by various laboratory tests, radiographic and oscillographic studies, observation of local temperature response after peripheral nerve block, and re-examination during and after various treatments. In addition to normals, the following types of case have been studied: arteriosclerosis with and without diabetes, peripheral thrombosis and embolus, thromboangitis obliterans, scleroderma, Raynaud's disease, Raynaud's syndrome, aneurysm, frostbite, immersion foot and essential hypertension. At present only a few individuals have been examined in each group but the several series are being steadily increased. To date approximately 60 patients have been studied.

The results obtained have been definite, objective and uninfluenced by the observer, the environment or the condition of the patient (except for his disease). Information obtained has supplemented clinical and laboratory methods yielding valuable data concerning the patency of the main and collateral circulation. In particular preoperative studies of patients coming to amputation have been valuable in confirming clinical impressions of competency of main or collateral circulation to permit healing below the knee joint. Further studies are projected to aid diagnosis and check results of treatments. It is felt that a sufficient number of tests have now been made to set up standards for subsequent study and to warrant the presentation of this preliminary report. A more detailed clinical study of illustrative cases is in preparation at the present time.

There have been no untoward local or systemic reactions to the use of the radioactive isotope. Many of the patients observed have been ambulatory, and have not required hospitalization for this study.

The radioactive sodium is prepared in the cyclotron by bombarding sodium metaborate with deuterons. The metaborate containing the active atoms is dissolved in water acidified with hydrochloric acid and treated with methyl alcohol. The resulting methyl borate and water are driven off by heating leaving sodium chloride. This is dissolved in sterile distilled water to give the desired concentration for injection and autoclaved for an hour.

The atoms of the radioactive isotope form a very small percentage of all the sodium atoms present. In 5 cubic centimeters of normal saline containing 200 microcuries (200 μ C) of radiosodium (which is more than is usually administered) fewer than 1 in 10 million sodium atoms are active; the rest are ordinary stable isotope. However, the ordinary and radioactive ones are indistinguishable and inseparable until the radioactive ones disintegrate. In the instant of disintegrating the radioactive atoms emit β particles and γ rays and become atoms of stable magnesium. The amount of magnesium thus formed is entirely too small to have any demonstrable effect, being for the quantities here cited of the order of a millionth of a microgram. The radiation is detected by the Geiger Mueller tube and the recording apparatus gives an audible click for every disintegration (or every 2, 4, 8, 16



Fig. 1. Measuring apparatus. Geiger Mueller counter in position against patient's foot.

or 32 disintegrations according to a scaling adjustment). The amount of radiation the patient's body receives in the total disintegration of the amount under discussion is less than 1 roentgen.

The experimental procedure which has been found most useful is as follows. The Geiger Mueller tube is placed against the sole of the foot to which the circulation time is desired as shown in Figure 1. The solution to be administered is carefully measured in a syringe, precautions being taken to assure that none is spilled anywhere in the room and that none gets on the hands of the person making the injection or handling the counter. The amount used varies from 50 to 300 microcuries of ra-

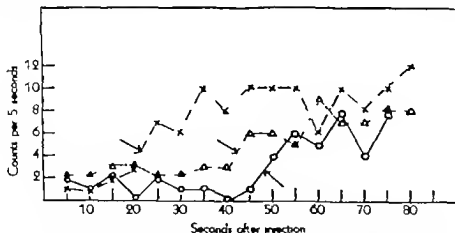


Fig. 2. Curves showing method of determining circulation time. Each type of symbol represents one case. Injection time 5 to 7 seconds. Arrows indicate point at which count rises definitely above background.

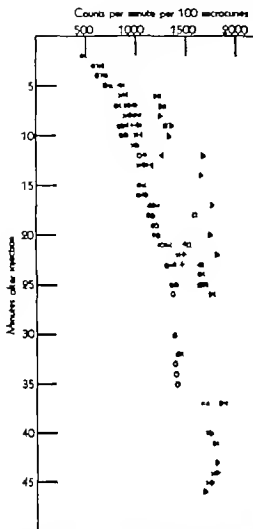


Fig. 3. Normal. Data showing build-up in counting rate 1 foot in period immediately following injection. Each type of symbol represents one individual. No difference ever observed between right and left foot.

diosodium depending on the length of time the test is to last what blood studies are to be made, etc. It is contained in from 3 to 10 cubic centimeters of normal or nearly normal saline. While the syringe containing the material is held close to the site of the injection (usually an antecubital vein) the scaling device on the counter is adjusted so that 1 or 2 clicks are heard each 5 seconds. These are due to cosmic rays and other background radiation as well as to the effect of the radioactive material to be injected. The injection and the electric

stop clock are started simultaneously counts are recorded every 5 seconds the time of the end of the injection also being noted (The injection is made as rapidly as feasible through a No. 18-20 gauge needle.)

When the material reaches the foot number of clicks per 5 seconds increases definitely and sharply the 5 second counting is however carried on for about a minute longer to be sure that no erratic background has been mistaken for the arrival of the material. After this, counting is carried out minute by minute as the build up to equilibrium proceeds. After 10 or 15 minutes (or sometimes less) the counter is shifted to the other foot. Subsequently measurements are made at various regions of the legs, arms, hands, etc. with frequent return to the feet.

The 5 second data may be plotted as shown in Figure 2 for the determination of arm-to-foot circulation time (or it can be estimated directly from the data). Circulation times have been determined in 45 individuals the average value was 45 seconds but the range was considerable. The highest was 90 seconds in an elderly diabetic arteriosclerotic woman who was fibrillating at the time of the test. The lowest was 15 seconds in a young man with a pulse of 100 suffering from scleroderma. In 15 individuals considered to be normal as far as circulation was concerned 12 fell between 45 and 55 seconds, two were 60 and three 35 or 40 seconds. In 5 patients with thromboangitis obliterans circulation times were all below 35 seconds. Seven arteriosclerotics showed a range between 30 and 80 seconds. There seems to be a correlation of the circulation time with the stage of the disease. Four cases with ulceration and inflammation (3 diabetics) showed times below 35 seconds.

Hubbard Preston and Ross have employed radiosodium in a somewhat similar manner to determine circulation time in infants their method of registration appears to have been more complicated than the one herein described (1).

More promising than circulation time as a clinical aid is the curve of equilibrium build up. Figure 3 shows data for the first 45 minutes for 8 normal individuals whose weights varied from 50 to 75 kilograms. (No adjust

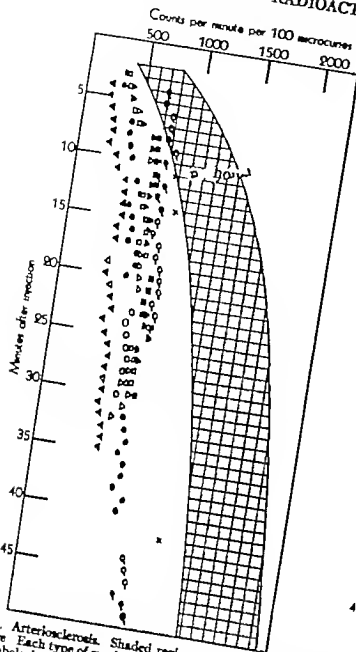


Fig. 4. Arteriosclerosis. Shaded region represents normal range. Each type of symbol represents one individual, open symbols, left feet, closed, right feet. Little difference between feet in any case.

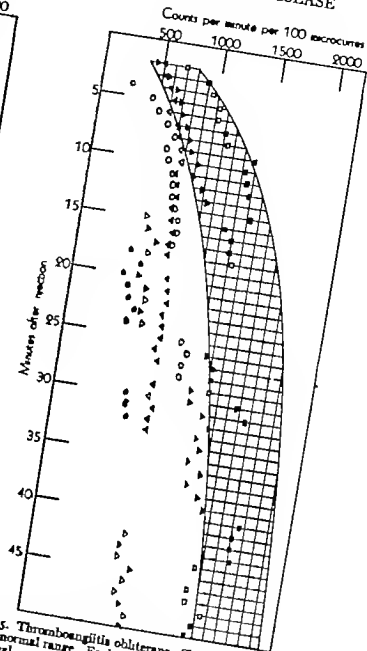


Fig. 5. Thromboangiitis obliterans. Shaded region represents normal range. Each type of symbol represents one individual, open symbols, left feet, closed, right feet. Considerable differences between feet in some cases.

ment is made for variation in weight.) Each type of symbol represents data for one individual. It is not feasible to indicate which were for right and which for left foot but in every case both were counted and there was no measurable difference. During the next hour the values increase by about 25 per cent and in the following 24 hours possibly 10 per cent more (allowance of course being made for radioactive decay). Excretion in the first 24 hours is not normally more than 5 per cent and probably less. Measurement of total urinary excretion in 2 normal individuals gave 2.5 per cent of the injected radiosodium in the first 18 hours.

Results obtained in various types of vascular disease are shown in Figures 4 to 7. In each of these the region in which all normal cases fell is shown as a shaded band. In each one type of symbol represents one individual, open symbols being counts for left feet, closed symbols for right feet. It is seen that in some diseased individuals the counts fell within the normal range although most were below

CLOSURE OF THE OPEN CHEST FOLLOWING THE SCHEDE OPERATION FOR TUBERCULOUS EMPYEMA

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THE present day radical surgical treatment for tuberculous empyema has been so successful that not only have many lives been saved but also many individuals have been enabled to return to useful pursuits in life. However this operative treatment still falls short of its maximum achievement because of the length of time required to control the empyema and to discharge the patient from the hospital with a healed wound. Therefore our efforts should henceforth be directed toward reducing anatomical deformity conserving musculoskeletal and respiratory function and expediting the healing of the open chest wound.

The present study concerns the author's experience in closing wide open chest wounds following the Schede operation by subtotal scapulectomy and plastic muscle flaps. The results are presented in a group of 6 patients who have had what is today considered the most effective type of surgical treatment for tuberculous empyema namely an open thoracotomy for empyema drainage followed in a few days by a thoracoplasty with the removal of at least 5 upper ribs, and subsequently by the radical Schede operation. The Schede procedure removes the entire roof of the empyema cavity. This consists of thickened parietal pleura ribs that have regenerated following thoracoplasty and the remaining intact ribs which still overhang the pleural space. The result is a wide open chest and a saucerized empyema cavity in the bottom of which one can see the collapsed lung covered only by visceral pleura (2).

This method of treatment is prescribed for tuberculous patients with evident bronchopleural fistulas, as for example in frank mixed infection pleural exudates or in empyema fluids with a high Gaffky count. In the latter it is believed that a small fistula opens and

closes intermittently and soon causes severe infection in the pleural lining and eventually in the uninvolved lung parenchyma. The presence of such a fistula also predisposes to brain abscess and cerebral air embolism (5). Strangely enough most of these patients have controlled underlying pulmonary disease but are now suffering from one of the complications of tuberculosis the empyema. As pointed out by Alexander the absolute number of both pure and mixed tuberculous empyemata has increased because of the increasing use of artificial pneumothorax.

PATHOLOGY

The open chest following the Schede operation presents one of the largest post-operative wounds encountered anywhere in the body. The condition and appearance of the wound will depend upon the time that has elapsed since the Schede operation and the amount of healing that has taken place. One is amazed at the lack of severe pain or discomfort with such extensive exposure of the lung and other tissues. The answer apparently lies in the fact that marked paradoxical breathing and severe anoxia are absent because of the fixed mediastinum. This thickening of the parietal pleura accompanying the empyema involves not only the pleura of the chest wall but also the pleura of the mediastinum. In this manner the mediastinal structures are immobilized. Thus, there is a limited shift of the heart and great vessels with each respiratory movement, and a rigid medial wall for the contralateral lung. The result is very little interference with respiratory function in the opposite lung. It is this "thickened pleura mechanism" with a fixed mediastinum that also permits the removal of 5 or more ribs in one stage of thoracoplasty prior to the Schede operation without great paradoxical breathing or operative shock to the patient.

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The pleural thickening is confined principally to the parietal layer and measures 2 centimeters to 2.5 centimeters in many cases. The thick edges of this pleura may be seen all around the lung margin after the unroofing by the Schede operation. On the other hand the visceral pleura is rarely more than 0.2 to 0.5 centimeter thick, and usually contains fistulas of varying sizes. Sometimes these fistulous openings may be large in size and lined with scar tissue. Often they present the familiar hissing sound of an open fistula.

an extensive Schede operation with a resulting large open chest. Therefore his lung will be more collapsed and he will show greater damage to the musculoskeletal structures of the thorax. The lack of a normally rigid chest wall is of no help in the re-expansion of this collapsed lung. The result is a degree of anoxia consistent with the loss of ventilating lung tissue. In addition if open fistulas are present they tend to perpetuate the collapse of the lung. Some paradoxical breathing may be present and in patients whose left chest is involved cardiac pulsations are clearly visible under the collapsed lung.

This gross pathological picture of thickened pleura, triangular ribs and narrowed intercostal spaces is the result of nature's attempt to obliterate the empyema cavity but she does not succeed. If observed several months after operation such wounds display much granulation tissue with shrinkage of the exposed lung area and infolding of skin around the wound's edges. The scapula with its flat surface forms a distinct bony roof or plate covering the cavity at the bottom of the chest wound. Only when the scapula is forcibly elevated can one see the full extent of the remaining pleural space. Skin and fibrous tissue grow under the vertebral border and under the lower angle of the scapula more than anywhere else. The size of such wounds depends on the size of the empyema cavity present before thoracoplasty. If the upper lobe was adherent to the top of the hemithorax during the empyema only a limited pleural space remains. However if the lung was greatly collapsed and the empyema was a universal one and reached the top of the chest the resulting wound is very large with a good sized sinus extending high up under the scapula. Fortunately in many cases the upper portion of the empyema cavity has been greatly diminished in size by the previous thoracoplasty with a dropping of the apex of the pleural cavity 2 or 3 inches. In fact some empyema cavities are represented after thoracoplasty and Schede operations only by a long narrow vertical sinus which extends upward under the scapula.

Such chest wounds are usually dressed each day with gauze packs soaked in antiseptic solutions or sulfonamide compounds. These dressings are painful and help prolong the infection. A seropurulent discharge saturates the dressings as nature tries in vain to shrink and close this large wound. Bacteriological studies usually reveal that the tubercle bacillus has disappeared from the secretions early especially if no cavities are present in the lung parenchyma and if fistulas are closed. Only the usual pyogenic organisms are found with or without secondary contaminants.

In general these patients are up and about the hospital wards and do not seem very ill in spite of the fact that most of them suffer from amyloid disease of a severe degree. However since the Schede operation has completely unroofed the suppurative pleural cavity and removed the infected parietal pleura they become fever free and improve steadily. They feel so well that at first the suggestion of a plastic operation to close the open chest meets with a negative response. They consider themselves fortunate to have survived so many operations and to have lost their toxemia. Usually they express a determination to have their chest wounds heal without further surgery. However considerable musculoskeletal deformity of the involved chest slowly develops and the patient is bent over to the side with only limited use of the homolateral shoulder girdle and trunk muscles.

PRINCIPLES OF THE OPERATION

The closure of tuberculous empyema cavities has been practiced for many years with a

The involved side of the chest moves very little with respiration due to the exposed and collapsed lung atrophy of muscles and the removal of the bony chest support. If a patient has a large empyema cavity he requires

varying degree of success. The more common practice has been not only to unroof the pleural cavity with a Schede thoracoplasty operation but *at the same time* to fill in the resulting chest defect with muscle flaps. Most of these operations were unsuccessful in our hands. Careful study revealed that the infection present prevented the flaps from adhering to the lung surface and pockets of pus were created. In some instances the tubercle bacilli flourished and rapidly grew in the muscle tissue thus spreading the disease. The same observation of tubercle bacillus growth in muscle implants was made by Auerbach who studied the postmortem material of patients who had had an unsuccessful one stage closure of tuberculous pulmonary cavities with muscle flaps. The only failure in the herewith reported series of cases is that of the 6th patient who possessed an undiscovered open cavity in the lung at the time of operation. The result was a rapid spread of the tuberculous infection throughout the wound and a hematogenous involvement followed by death. When primary closure of empyema cavities has been attempted the operative mortality has been very high since these patients represent the poorest surgical risks and cannot tolerate too long and too mutilating a surgical procedure.

Some thoracic surgeons have mobilized and cut muscle pedicle flaps at the time of the Schede operation with the intention of implanting them at a later date but the results have been found unsatisfactory. At operation we find such muscle flaps atrophied and heavily infiltrated with fibrous tissue. Evidently the proximity of infection to a loosened muscle mass deprives it of viability. In addition it lacks the protection of its normal fascial coverings in the musculoskeletal system and the mobilization procedure interferes with its vascularization. From these observations it was subsequently decided only to unroof the cavity at the first sitting and after several months have elapsed to proceed to plastic muscle closure. During this time the patient loses his toxemia the wound becomes cleaner and the troublesome tubercle bacillus disappears.

However several factors must be carefully considered before the thoracic surgeon can

hope for a successful muscle plastic closure of an open chest wound.

1. *Bronchial fistulas* must be closed. As stated previously the presence of fistulas is the usual cause of the severe tuberculous empyema. Even if the fistulas are not visible at operation they may still become patent from time to time. These fistulas must be completely obliterated if one wishes to eliminate further contamination of the wound by pyogenes. The latter are always present in the bronchi. Suturing the bronchial ostia as a method of closure is useless. The only successful procedure is the application of a muscle flap. Abrashanoff in 1911 was the first to use a pedicled muscle flap placed over the mouth of a bronchial fistula. Since that time many surgeons have made use of this principle and the results have been satisfactory. Pool and Garlock closed larger bronchial fistulas by placing muscle grafts directly into them. They showed by animal experiments that the graft becomes firmly united to the wall of the bronchus, and in the gross there is evidence of the outgrowth of bronchial epithelium to cover the muscle flap. There is no evidence to indicate the presence of inflammatory reaction in the adjacent lung parenchyma.

As applied in this operation for the closure of the open chest following Schede a large mass of pedunculated muscle has the added advantage of compressing the fistulous ostia. The result is a firm, permanent closure. This method of bronchial fistula closure has stood the test of time (5) whereas the use of other tissue grafts such as skin or fat has resulted only in failure.

2. *The chest wound must be satisfactory for closure.* The Schede operation should leave a "saucerized cavity" that is, a flat wound without overhanging edges of thickened parietal pleura or rib stumps. This eliminates the formation of pockets of fluid which may dissect the muscle flaps off the lung surface. No abscess cavities or sinuses should be present. If found, they must be so treated that only one cavity remains before insertion of the flaps. The area of chest wall surrounding the wound should be even and free from prominent flaring ribs. If muscle pedicle flaps must pass over irregularly projecting ribs be-

fore they reach the empyema cavity they would require greater lengths of muscle and nutrition to grow effectively.

The presence of the usual pyogenic infection that occurs several weeks or months after the Schede operation does not materially affect the growth of muscle flaps. The experience gained in the present group of cases taught us also that the implanted muscle should be large enough to fill the empyema space completely. This concept differs from the experience of Robinson whose opinion it is that muscle grafts should occupy only part of the space in order to allow room for the evacuation of purulent secretions and for the local treatment of the suppurative pleural lining. However we have found that after the Schede operation most of the original virulent organisms disappear over a period of a few months because of adequate drainage and through treatment with antiseptic solutions and sulfonamide compounds. Those that remain are only the usual contaminants of large wounds. Tubercle bacilli may be present in the caseated areas of sinuses high up under the scapula where it is always difficult to expose the parietal pleura. Caseated lung tissue may also harbor the tubercle bacillus and pass unnoticed as in Case 6 but fortunately such occurrences are rare. Therefore frequent bacteriological studies should determine the time of closure of the open chest wound. If tubercle bacilli are re-covered plastic closure should be deferred until they are no longer present.

3 *Resection of the scapula* This bony structure is one of the causes of the long delay in the healing of post Schede wounds and should be resected in all muscle plastic closures. The flat surface of the body of the scapula forms a roof over the cavity. Not only is packing with gauze made difficult after the Schede operation but a pleural cavity of large size may form a long sinus completely hidden beneath the scapula. As will be seen later a resection of the lower one third to one half of the scapula gives access to this upper pleural space. It also makes available the attached infrapleural and subcapular muscles as part of the fill and increases the length of the latissimus dorsi flap. All of the

scapula below the origin of the spine should be resected.

Resection of the scapula is followed by surprisingly little deformity or functional disability of the shoulder and upper extremity. Prior to plastic chest closure and scapular resection some deformity and incapacitation is already present because of the thoracoplasty and Schede operations. In addition prolonged suppuration over a period of months with daily packs and dressings has caused fibrous tissue formation and immobilization of all in volved chest structures.

As to the disability caused by scapula resection Coryllos and Weinstein have pointed out the following. By virtue of its anatomical structure and position the scapula blade forms the posterior portion of the girdle supporting the arm. The shoulder girdle which is attached to the chest only by the sternoclavicular joint is closely applied to the thorax by means of many powerful muscles. It is suspended directly by the muscles trapezius, rhomboidii and angularis and indirectly by the scalenus anticus and sternomastoid which are attached to the clavicle. Fixation to the chest is accomplished by the powerful serratus and the small serratus posticus superior. At its inferior angle it receives a few fibers from the latissimus dorsi. These multiple muscular insertions explain the good function of the scapula and arm even though a great part of the trapezius, rhomboidii and the serratus are sectioned during thoracoplasty. Resection of the scapula does not interfere with the movements of the shoulder joint itself. Furthermore partial regeneration of the bone permits some resumption of function of the muscles attached to the scapula.

4 *Advantages of muscle grafts* Since all the viscera within the thorax depend upon a rigid chest wall for proper cardiac and respiratory function one should endeavor to repair and cover chest wall defects with as firm a tissue as possible. Next to bone and cartilage muscle is the best available tissue that has bulk and substance. Besides its properties of growth and firm attachment to surrounding structures even in the presence of infection make it especially adaptable for the filling of large chest defects. The preparation of muscle

fills should be accomplished with as little trauma to the pedicled graft as possible so that tissue viability may be retained. Clamping of the muscle, especially the detached end, only predisposes to necrosis and a failure to adhere and grow. The graft should be so fashioned that the attached end remains close to the vascular supply so that adequate nonre-ishment may be maintained.

Since the modern thoracoplasty operation involves the posterolateral portion of the chest and is followed in this region by the Schede operation, the available muscles for closure are the sacrospinalis, latissimus dorsi, trapezius, and scapula muscles. Therefore all preliminary operations that involve these muscles should be so carried out that a minimum of muscle tissue is sectioned or traumatized. For example when thoracoplasty is done the latissimus dorsi muscle can be mobilized and not sectioned if good wound exposure is desired. However if muscles are severed during the operation careful suturing should be done to accomplish good approximation and firm healing. In other words, as soon as radical surgery is planned for tuberculous empyema patients, one should conserve all available muscle tissue so that plastic closure may be accomplished at a future date with untraumatized and well vascularized musculature.

5 Mechanics of muscle fill for the open chest. The trapezius muscle is not very important in shaping muscle grafts. It is a broad, flat triangular muscle with its base at the median line and its apex at the acromion process of the clavicle. It cannot be fashioned into a long pedunculated flap but it may be utilized with the rhomboid muscles as part of the superficial muscle group that remains after the scapula is resected. However the trapezius is very often thin and worthless because of muscle atrophy since previous thoracoplasty operations have sectioned it one or more times.

The scapula muscles, however, are valuable for muscle fills since they are in closest relation to the superior portion of the empyema sinus. After removal of the lower third or half of the scapula bone the infraspinatus and subscapularis readily drop into the sinus. If a

long high apical sinus is present because of a complete empyema cavity the scapular muscles cannot reach the uppermost limit. To fill in this area the latissimus dorsi is used. In order to secure a long muscle flap a piece of latissimus must be dissected almost as far down as its origin on the posterior third of the iliac crest. Above the latissimus dorsi is left attached to the lower end of the scapula and close to the infraspinatus muscle so that after scapula resection it may be rolled under the remaining bone as part of the entire muscle mass. The latissimus dorsi muscle is ideally situated for empyema cavity fills in that it is located just at the anterior border of the open chest. An additional advantage in using this muscle is the fact that, unlike many other muscles used for pedicled muscle flaps, it contains a minimum of tendinous or aponeurotic tissue. This makes for rapid and effective union with underlying structures. In small empyema cavities a scapula resection with a latissimus dorsi muscle flap may be all that is necessary for good closure. However most residual pleural spaces are large and therefore require more muscle to complete the plastic procedure. We then must make use of an additional muscle the erector spinae located posteriorly.

The erector spinae muscle normally fills in the hollow on each side of the spinous processes. It is more bulky than the latissimus and fortunately has not been traumatized by previous operations. When mobilized it can form a pedicled muscle flap of considerable length and breadth. Its location is too far posterior to make it available for filling in the apex of a long empyema sinus. Besides, it would describe too circuitous a course around and under the scapula to reach that place. Better use can be made of it to cover the exposed lower lung area, especially since it can form a long wide muscle mass sufficient to cover a large surface.

ANESTHESIA

Inhalation anesthesia is the method of choice and in our hands cyclopropane has been very satisfactory. An intratracheal catheter is unnecessary since these patients expectorate little and are never in danger of inundation by bronchial secretions. The lung

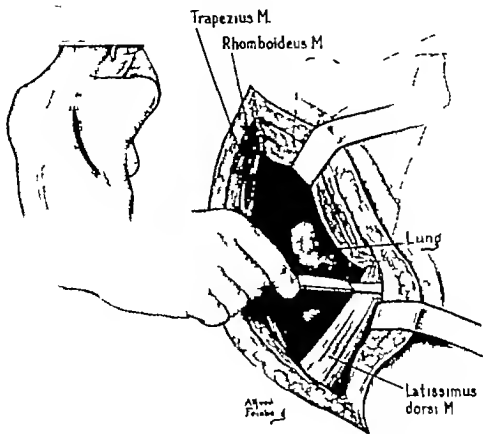


Fig. Freeing of latissimus dorsi muscle preparatory to severing it below from its attachment to iliac crest. Insert illustrates incision of old scar

surface is well within view throughout the operation and can be kept covered by hot packs and aspirated free of blood and secretions. As soon as the muscle flaps are inserted into the residual pleural space the open bronchi are plugged and the external communications of the bronchial tree are thus closed.

Throughout the operation the anesthetist should carefully record the pulse and blood pressure since these patients may quickly plunge into shock from the blood loss and operative trauma. They usually come to operation with a diminished blood volume and a lowered vital capacity while many of them suffer from avitaminosis and extensive amyloidosis. For these reasons citrated blood plasma and glucose with saline are administered during the procedure by means of a cannula sutured into the internal saphenous vein.

OPERATION

Incision. The incision represents an excision of all the old scars resulting from the

posterolateral thoracoplasty and Schede operations (Fig. 1). Scar tissue is too poorly nourished to be used for suturing or for any type of plastic closure. The resected wound margin also includes granulation tissue and in folded skin up to the visceral pleura. A large amount of skin has grown under the vertebral border of the scapula and this must also be removed. To dissect and mobilize a long flap of latissimus dorsi it is usually necessary to make an additional vertical skin incision of 2 to 4 inches downward toward the iliac crest. Following this the deep fascia all around the wound is separated from the subcutaneous fat by sharp dissection for a distance of one half to one inch beyond the line of incision thus mobilizing the extracostal muscles and preparing the wound for rapid closure at the end of the operation.

Procedure. A rapid search is made for sinuses and abscess pockets by direct vision probing with the gloved finger and instrumentation. If these are discovered they

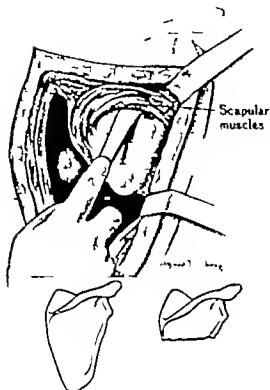


Fig. 2 Separation of infraspinatus and subscapularis muscles from inferior angle of scapula, prior to subtotal resection of this bone. Inserts demonstrate box flap of scapular and latissimus muscles is lengthened by scapular resection since it will be turned under scapula to reach apex of space.

should be unroofed, excised, or curetted. The visceral pleura covering the lung is not interfered with in any way whatsoever since procedures such as curetting or cross-hatching may give rise to additional fistulas or fatal air embolism.

The operator's attention is next directed to the upper portion of the residual empyema cavity where one estimates the amount of latissimus dorsi flap that would be necessary for closure. If the patient originally had a limited pleural cavity because of fixation of the upper lobe to the chest wall, then less muscle will be needed and the problem is relatively simple. If the cavity is extensive considerable muscle tissue will be required. The latissimus is carefully dissected with the scalpel both superficially from the subcutaneous tissue and deeply from the chest

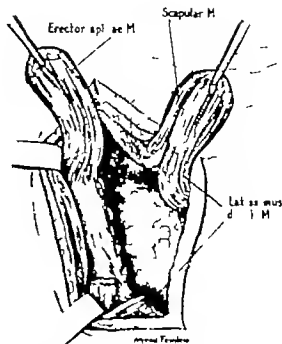


Fig. 3 After resection of lower scapula, latissimus dorsi and erector spinae muscle flaps are fashioned and made ready for implantation.

wall (Fig. 1). Two or more Kocher clamps are placed distal to the line of proposed sectioning and the muscle is incised proximal to the clamps. In this manner the muscle fibers to be used in the flap are not traumatized. Suture ligatures around the clamps control bleeding from the remaining muscle stump close to its attachment to the crest of the ilium.

The lower third to one half of the scapula is now dissected in the manner described in detail elsewhere (4). The resection extends upward on the flat body of the scapula to a line corresponding with the origin of the spine from the vertebral border (Fig. 2). This procedure reveals a large muscle mass containing the detached subscapularis and infraspinatus muscles. Thus, these muscles are now lengthened as is also the latissimus dorsi. The latissimus muscle is dissected posteriorly from the lumbar fascia and together with the scapular muscles, the trapezius, and rhomboids, forms a large sized pedicled muscle flap (Fig. 3). The end of the latissimus is folded

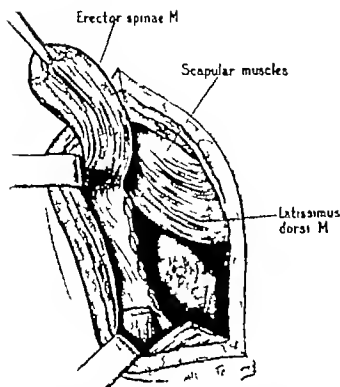


Fig. 4. Latissimus dorsi muscle turned under remainder of scapula and sutured into place. The upper portion of the exposed lung is thus covered, and the top of the remains of the pleural cavity filled.

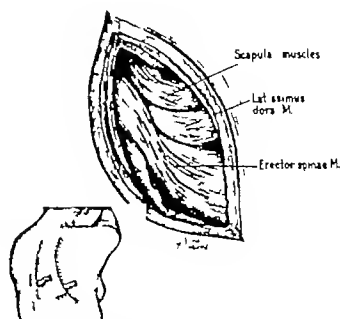


Fig. 5. Erector spinae muscle spread out over lower portion of lung. Insert shows wound closure with two Penrose drains, the posterior one for the dead space created by removal of erector spinae muscle.

upon itself and forced upward to fill the apex of the pleural sinus. Since this area is now plugged with a muscle fill, it is usually impossible to fix the end of the muscle to the highest point of the sinus by suture. More over this is unnecessary since several interrupted catgut sutures placed in the chest wall structures just beyond the lung margin will maintain the mass in place. The cut edge of the trapezius and rhomboid muscles, if large enough, are crowded into the space and also sutured to the paravertebral edge of the wound (Fig. 4).

However, in large open chest cavities the lower portion of the lung is still exposed. To cover this the erector spinae muscle is utilized. Dissection is carried along this muscle laterally where it is attached to the ribs and medially as far down as the lumbar region where it arises from the spines of the lumbar vertebrae. When the proper length is mobilized, it is incised low down proximally to 2 or 3 Kocher clamps. The large muscle flap is now gradually raised off the ribs and vertebrae up to a point

that gives it enough length completely to cover the lower and remaining exposed lung. Interrupted catgut sutures affix it to the chest wall tissues beyond the lung periphery so that the latter is completely covered with an adequate amount of muscle. The residual pleural cavity is now obliterated by muscle fill, and the lung is no longer exposed (Fig. 5).

Closure. The wound is ready for closure and the muscle layer mobilization that was done immediately following the incision permits an accurate and quick approximation of skin and subcutaneous tissue. Interrupted silk or nylon Stewart sutures are used, care being exercised not to place too many sutures in areas likely to become necrotic as in the pointed corners of skin flaps. The removal of the erector spinae muscle leaves behind a space that is certain to collect serosanguinous fluid. A stab wound is made in this area, low down and a rubber tissue drain inserted. Another drain is usually placed somewhere in the suture line on the lateral chest wall below the scapula.

The dressings are placed snugly, preferably with sea sponges incorporated in them so that the flaps will be well applied to underlying surfaces and collections of fluid thus avoided. The arm is strapped to the chest by adhesive

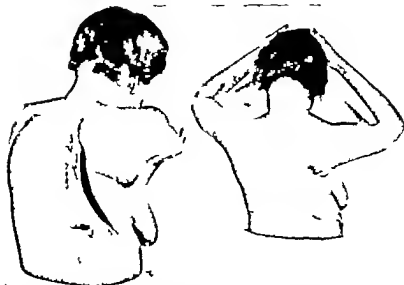


Fig. 6, left, Wide open chest with exposed collapsed lung following two stages of thoracoplasty and radical Schede operation.

Fig. 7 Chest successfully closed by latissimus dorsi muscle graft and subtotal scapula resection.

in order not to disturb the attachments of the muscle flaps.

POSTOPERATIVE COURSE

Once these patients react from their operation their course is smooth and uneventful. Additional blood and plasma may be required from time to time. Anoxia and respiratory disturbances are usually not severe. The elimination of a suppurating chest wound with open bronchial fistulas diminishes the toxemia, and the patients gradually improve. The first dressing is postponed for one week to give the muscle flaps a chance to affix themselves to underlying structures just as in skin grafting. The drains and all sutures are removed at the same time. After 5 or 6 weeks if the wounds are almost closed the patients may leave the hospital.

CASE REPORTS

The foregoing operative plan for closing the open chest was decided upon after a disappointing experience with 2 patients. The first patient R.M. had two stages of thoracoplasty a Schede operation with scapulectomy two operations for revising the previous Schede and finally a third Schede revision operation. During this third Schede

revision (by the author January 20 1939) a large number of suppurating sinuses were encountered arising from osteomyelitis of intact ribs rib stumps, regenerated ribs, and scapula. The operation consisted of unroofing or excising all involved areas of suppuration and the removing of osteomyelitic bone. An attempt was then made to cover over a small area of exposed lung by a flap of latissimus dorsi. This muscle was small and atrophied from the previous surgical procedures. The muscle flap failed to take the wound became extensively infected and a few months later the patient developed cavity disease of the contralateral lung with severe and repeated hemoptyses. He expired 7 months later. The second patient R.B. had a tuberculous empyema which was treated by thoracotomy and thoracoplasty on January 27 1939. Following this, an attempt was made to combine the operation of Schede with scapulectomy and muscle flap closure all in one stage. The result was unsuccessful because the suppuration present was too extensive and the organisms too virulent. The profuse drainage from the wound loosened the implanted muscle flaps and a large portion of the empyema cavity persisted.



Fig. 8, left, An extreme case of a wide open chest in a female patient who weighed under 80 pounds. This condition resulted from a tuberculous empyema with extensive streptococcus infection of extrapleural space.

Fig. 9. Successful closure after revision of many sinuses and the removal of much osteomyelitic bone. Scapula resected and latissimus dorsi muscle implanted. Good arm function.

A decision was then made to perform the muscle plastic operation only if the following conditions prevailed (1) relatively clean wound free from tubercle bacilli and other virulent organisms (2) granulating wounds well saucerized with no overhanging ribs or tuberculous pleura (3) patients without the toxemia that results from unroofed empyema cavities

CASE 1 Patient C.N. a colored female 28 years of age became ill July 1935. Pneumothorax was instituted on right side August, 1935. Fluid developed November 1935. Repeated aspirations yielded sterile fluid. She entered Sea View Hospital March 16 1936 and was discharged in July 1936 as an arrested case. Sputum was negative and during her stay fluid was sterile. She was followed in clinic, had refills every 3 weeks and in February 1937 was told that fluid had disappeared. In February 1938 she began to streak sputum turned positive. She was readmitted to Sea View Hospital in July 1938. Fluid now showed Gaffky III sputum Gaffky IV. In November 1938 she expectorated methylene blue from pleural cavity. no fever was present.

Thoracotomy was performed November 4 1938 involving 6th right intercostal space. First stage thoracoplasty was done on November 11 1938. Upper three ribs were removed. To provide better pleural cavity drainage, a 12 inch segment of 9th rib was removed and large tube inserted. Second stage thoracoplasty was done December 16 1938 and 4th,

5th and 6th ribs were removed. Schede operation was performed January 6 1939. Extensive unroofing of empyema cavity was accomplished by removing regenerated ribs 7th 8th and 9th intact ribs and all parietal pleura. Cavity was left wide open and packed with gauze. Patient was markedly shocked. Operative time was 24 minutes. Pathological report revealed Areas of caseation in parietal pleura diagnosis tuberculous empyema wall.

Muscle flap closure of chest was carried out February 24 1939. Complete empyema was present with wide open chest and clean and granulating wound (Fig. 6). Wide excision of scar and inverted skin was made and lower one third of scapula resected. Flap of latissimus dorsi was sutured into wound with scapula muscles. Small, lowermost portion of wound was covered only by skin and fat since muscle flap was inadequate to cover entire area. If patient were not muscular additional muscle as erector spinae, would have been necessary. Primary closure of wound was done with interrupted silk sutures. Postoperative course was uneventful. The wound drained serosanguineous material but healed by primary union in 17 days (Fig. 7).

CASE 2 Patient C.N. a white female 26 years of age was admitted to Sea View Hospital, August 23 1937. There was history of onset of disease in February 1936 with cold cough fever and loss of weight. Sputum examination was negative but gastric positive.

Pneumothorax was done on September 9 1936. Fluid developed in January 1937 which was negative for tubercle bacilli and pyogenes. On February 28 1937 two days after a refill patient developed



Fig. 9. Left. This picture does not portray the full extent of the open chest since the arm is held close to trunk. Following the Scheele operation the wound is unusually large because in addition to removing complete empyema, supporting extrapleural space is widely excised.
 Right. Wound healed by primary union within 4 weeks. Arm function not greatly restricted.

temperature of 104 degrees F and fluid now contained *Streptococcus hemolyticus* but no *t. berche* bacilli. She again received *Antistreptococcus serum* and protargin and irrigated the anechloramm. Fluid was negative for *Streptococcus* and *tubercle* bacilli, and has remained negative since April, 1937. Sputum and gastric examinations were negative; patient never expectorated methylene blue. She left hospital gain in weight with 90 per cent collapse of right lung.

Patient was readmitted 2 months later with history of having been very ill with fever, dyspnea and the rapid accumulation of fluid. Fluid was thick and bluish green, the hemolytic *Streptococcus* but no *t. berche* bacilli. Patient was given *Antistreptococcus serum* and protargin again tried but there was no pronounced improvement. Sputum and gastric examinations were negative. Lung failed to re-expand.

First stage thoracoplasty was performed on December 21, 1937. Upper three ribs were removed under local anesthesia. Procedure was followed by severe *Streptococcus* infection of entire wound. Thoracotomy was done on March 2, 1938. Tube was inserted in 6th interspace midaxillary line. Second stage thoracoplasty was performed on August 2, 1938 and 4th, 5th and 6th ribs were removed. Entire chest wall was a wide open purulent cavity because of the additional trypalear infection. Scheele operation was performed September 6, 1938 and 7th and 8th ribs were removed. Parietal pleura was excised together with all regenerated bone. Large sacculated cavity resulted (Fig. 8).

Muscle plastic operation was performed on October 6, 1939. Sinuses were opened and excised

and osteomielitic bone removed. Subtotal resection of scapula was carried out. *Latissimus dorsi* mobilized and sectioned low down together with infraclavicular vessels attached to top of pleural cavity. However, muscle still barely covered remaining lung. Primary closure of chest wall was made. Penrose drain in lower angle. Operating time 2 hours 45 minutes. Wound well healed after several weeks (Fig. 9). There was never any purulent drainage. Convalescence was delayed by a severe attack of generalized ribitis. Patient was discharged March 2, 1940.

This patient presented the poorest operative risk of the series because of the severe mixed infection empyema with *Streptococcus hemolyticus* and the complicating thoracoplasty wound infection. Her weight during the Scheele and muscle plastic operations was less than 90 pounds, vital capacity 900 cubic centimeters. Follow up examination on November 5, 1943, revealed a well patient weighing 120 pounds and working as salesgirl in a retail store 5 days a week.

CASE 3. Patient M. F., a white female 3 years of age, was admitted April 2, 1942. Her chest wall was collapsed by several operations, and the operative scars contained four draining sinuses. The diagnosis of pulmonary tuberculosis was made in 1930. In October of that year pneumothorax was induced subsequently followed by thoracoscopy. A right pleural effusion developed and her sputum became



Fig. 12, left. Six ribs removed at thoracoplasty operation followed by a Schede procedure. Wound failed to close after 2 years of daily dressings and in spite of a supplementary anterior thoracoplasty operation. Scapula forms a distinct roof over a large loculated area of pus.

Fig. 13. Adequate filling of space with firm closure resulted from resection of scapula and the implanting of latissimus dorsi and erector spinae muscles.

negative. In September 1940 mixed infection empyema developed.

First stage thoracoplasty was carried out in December 1940. Wound became infected. Thoracotomy was done in January 1941. Second stage thoracoplasty was performed in April 1941. Wound became infected. Third stage thoracoplasty was done in June, 1941. Wound infection developed followed by draining sinuses. She was then admitted to Sea View Hospital where upon admission and until discharge all sputum and gastric examinations were negative. Schede operation was performed on June 30, 1942. Four suppurating sinuses developed in operative scar connecting with a large infected extrapleural space which extended throughout the length and breadth of the hemithorax. A sinus tract was present in the outer posterior portion of the breast continuous with this large pocket of pus. There was no osteomyelitis of regenerated or unremoved ribs. On probing a sinus tract on lateral chest wall was found to enter an empyema cavity. The latter contained thick, gray brown pus, and reached to level of 3rd rib superiorly in the full anteroposterior dimension of the chest. Parietal pleura was three quarters of an inch thick. Complete unroofing of extrapleural space including breast sinus was carried out. Then pleural space was made continuous with extrapleural space by the excision of parietal pleura and regenerated ribs. Lower third of scapula was removed because it was adherent to ribs. Chest wall with exposed lung was left wide open and packed. Tissue removed at operation showed acute and chronic inflammation but no evidence of active tuberculosis. Subsequent smears showed no tubercle

bacilli but *Staphylococcus aureus* and *Bacillus coli* always present.

Muscle plastic operation was performed on June 4, 1943. Old scar was excised (Fig. 10). Latissimus dorsi was dissected free down to crest of ilium but this muscle was greatly atrophied. Therefore the erector spinae was mobilized for a length of 5 inches and both muscles were sutured into the pleural space covering the lung. Primary closure of wound was made with two drains. Wound was well healed within 4 weeks (Fig. 11).

At the end of the Schede operation this patient presented the largest chest wound of all the patients in the series. This was partly due to the fact that the large extrapleural space was opened as well as the pleural space. Evidently there was wound contamination by the empyema resulting in the infected extrapleural space. Only a moderate amount of shoulder and arm restriction resulted.

CASE 4. Patient I.N. a white female 37 years of age was admitted July 25, 1940 with a history of onset of disease in 1922 with cough and streaking. Pneumothorax was carried out in 1922. Two years later clear fluid developed. Patient returned home from sanitarium in 1928. No further refills developed. In March 1940 she had pain, dyspnea and fever. Aspiration yielded pus. Sputum was always negative. Methylene blue was never expectorated. Thoracotomy was performed in 1940 at another hospital. drainage tube was placed just



Fig. 14.



Fig. 5.



Fig. 6.

Fig. 14. The appearance of patient after an unsuccessful thoracoplasty. A large open chest with exposure of considerable lung tissue is present.

Fig. 5. Illustrating the failure of skin and subcutaneous tissue as sliding grafts for the closure of major chest defects.

A subsequent muscle plastic operation by the author yielded successful result.

Fig. 6. A few weeks after successful muscle plastic closure. Firm primary union, no more drainage. Patient now ready for active and passive motion.

below scapula in the 7th interspace. First stage thoracoplasty was done on October 8, 1940. Upper six ribs were removed. Schede operation was carried out on November 8, 1940. Pleural space was considerably smaller since thoracoplasty. 7th, 8th and 9th ribs were removed together with thickened parietal pleura and regenerated ribs. Patient was in poor condition throughout operation. Because patient refused a muscle plastic operation, anterior thoracoplasty was done to close remaining pleural space. Costal cartilages and inches of corresponding ribs were removed. However, shrinkage of space occurred because of "roofing mechanism" of scapula. Wound smears were always negative for tubercle bacilli (Fig. 1).

Muscle plastic operation was performed on June 21, 1943. Exposed lung measured 4 inches by 3 inches. Latissimus dorsi was atrophied and thinned out. Erector spinae seemed better nourished. Both muscles were implanted into space, after resection of lower end of scapula. Adequate filling of space resulted. At time of plastic operation patient's state of nutrition was poor, weight 93 pounds. Pus loculated under skin flap but within 3 months wound was well healed and patient ready for discharge (Fig. 3).

This patient presented an empyema space that resisted all efforts at healing, especially because of overlying scapula. Anterior thoracoplasty operation failed to close the space. Muscle plastic operation could have been performed 2 years earlier and probably would have shortened her hospital stay considerably.

CASE 5. Patient S.W., a white male, 30 years of age, was admitted to Sea View Hospital, August 1940. He had a history of onset of disease in July 1939, and was admitted to Kings County Hospital, November 1939. Pneumothorax was carried out in December 1939. Instituted on right side. Pneumothorax was attempted in January 1940. Fluid developed March 1940. On admission to Sea View Hospital, the pathology was right cavitary pneumonic tuberculosis with tuberculous empyema. Thoracotomy was done on November 6, 1940. Drainage tube was inserted between ribs. First stage thoracoplasty was carried out on November 5, 1940. Second stage thoracoplasty and Schede operation were both done December 10, 1940. Anterior thoracoplasty on February 27, 1943, was performed as an attempt to close the residual pleural space. But this was unsuccessful (Fig. 14). Closure of empyema space was attempted by a skin and subcutaneous tissue flap. Most of this sloughed, leaving behind extensive dense scar tissue (Fig. 5).

Muscle plastic closure on November 2, 1943, was performed by the author according to technique described. Lower half of scapula was resected. Latissimus dorsi was almost nonexistent from sectioning of previous operations. Therefore, a pedicled muscle flap was formed from erector spinae muscle, and this almost completely covered exposed lung. Skin edges were approximated, but under tension. However, wound healed by primary union (Fig. 6).

This case illustrates the failure in open chests to cover exposed lung simply by utilizing skin and fat pedicled grafts. An accom-

panying bronchopleural fistula cannot be closed by such means and only results in an infected wound with operative failure

This was the only failure and fatality in this series and in retrospect the following observations are significant (1) Such an emaciated individual was a poor subject for a muscle flap operation especially since at a previous operation the scapular and latissimus dorsi muscles were mobilized and severed. This procedure rendered them atrophic and useless as muscle fills (2) The underlying lung pathology was misjudged and its caseous nature was not realized until the time of operation. As a result not only was the tuberculous disease activated locally throughout the wound but a severe hematogenous spread resulted

CONCLUSIONS

1 A muscle plastic operation is described for the closure of the wide open chest following the Schede operation

2 The accepted treatment for tuberculous empyema is radical surgery thoracotomy thoracoplasty and Schede operations. The anatomical result is a wide open chest with exposed lung taking months and years to close if spontaneous closure takes place at all

3 A muscle plastic closure cannot be satisfactorily accomplished at the time of the Schede operation. The reasons are the toxic condition of the patient with an empyema cavity and the failure of muscle flaps to adhere in the presence of severe infection especially if the tubercle bacillus is a causative factor

4. The operation should be planned far in advance so that at the time of the thoracoplasty and Schede procedures a minimum amount of extracostal musculature will be traumatized or sacrificed

5 Small residual empyema cavities may be closed by resecting the scapula and implanting a pedicled flap of scapular and latissimus dorsi muscles. Larger chest defects require in addition a graft of erector spinae muscle to cover the exposed lower lung

6 Postoperative wounds heal by primary union as early as 4 to 6 weeks. On the other hand if left to close spontaneously patients with open chest wounds remain in the hospital as long as 3 years

CASE 6 Patient S C a Porto Rican male 30 years of age, was admitted to Sea View Hospital April 3 1941, with a history of disease first discovered in October, 1938, when roentgenograms and sputa were found positive. He was admitted to Sea View Hospital April 3 1941 with positive sputum. There was a left upper lobe cavity with an ineffectual pneumothorax and Gaffky VIII fluid Sputum turned negative. Fluid also contained pyogenes. Lung failed to re-expand with oxygen lavage. Sputum was again positive

Thoracotomy was performed on May 7 1942. First stage thoracoplasty was carried out on left side May 14 1942. Schede operation was performed May 28 1943. Parietal pleura and regenerated ribs were excised. In addition, scapula was resected and latissimus dorsi freed and cut in preparation for a muscle flap at some future date

12 1943 Patient was a thin emaciated male weighing about 75 pounds. At the Schede operation 5 months ago the scapula was resected and the latissimus dorsi completely freed and sectioned distally in preparation for a later muscle flap closure. However this muscle and the scapular muscles were hard fibrous, and atrophic because of previous mobilization. There was a draining sinus of caseated material and pus under the subcutaneous tissue overlying the scapula. Exposed lung measured 3 inches by 5 inches and the residual pleural space buried under the scapula. At the top of the space a loose sequestrum of bone was found. The patient's remaining pleural cavity was considered complete and extended upward to the apex of the lung

The operation consisted in making a muscle flap of the erector spinae since the scapular and latissimus dorsi muscles were atrophic and not supple enough to meet the requirements of muscle fills. All draining sinuses and caseated material were curetted and excised as thoroughly as possible. Skin and fat flaps were coapted completely to cover all raw surfaces.

This wound was totally different from any previous wound. Purulent material with muscle sloughs poured from the wound at each dressing. The wound edges separated and the muscle flap was observed to be entirely loosened and bathed in pus. The patient went steadily downhill, with high fever, rapid pulse and loss of weight. Pus and caseated material continued to bathe the entire wound. Patient expired December 18 1943 about 3 months following operation. A postmortem examination revealed an inspissated cavity of left lower lobe. The immediate cause of death was (1) bronchopneumonia (2) healed infarct left ventricle of heart (3) peptic ulcer (4) military tubercles of spine (5) tuberculous liver and prostatic gland (6) caseous tuberculosis of lungs.

7 Six patients have been operated upon according to this technique with success in 5 cases and failure in 1. All 5 patients are well enough to earn a livelihood in part at least, and 1 patient went through childbirth without incident.

8 The unsuccessful result occurred in an emaciated individual weighing about 75 pounds who had an unrecognized caseous focus in his lung at the time of operation. The result was extensive tuberculous infection in the wound and a hematogenous dissemination throughout the body.

9. The principles involved in this operation have been successfully used by the author in treating patients with chest defects resulting from nontuberculous empyema. The absence of tuberculous inflammation in such cases

makes for less chance of complications and more rapid wound healing.

Since the completion of this article for publication a 7th patient was operated upon at another hospital according to the technique described. The wound healed completely in 2 weeks at which time the patient was discharged from the hospital.

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HYPERACTIVITY OF VASOCONSTRICTOR NERVES IN RELATION TO SHOCK

An Experimental and Clinical Study

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IT is an old teaching that shock may develop as a complication of wounds and operations through the influence of the nervous system upon the circulatory system. The commonest theory of the method of action has been that vasodepressor nerve impulses are set up either by the wound or psychically which result in vasodilation and hypotension. Among the objections to this theory a serious one is that both clinical and experimental studies have shown that in shock the blood vessels have ordinarily been found in a state of vasoconstriction. The literature on this subject has been reviewed by Andrus. A common explanation given for the vasoconstriction is that it arises secondary to a reduction of the circulating blood volume and represents an attempt to adjust the vascular bed to the remaining blood volume thus maintaining an adequate circulation (3). As the blood volume is reduced there is a concomitant reduction in intravascular pressure which reduces the amount of stimulation of the carotid sinus and aortic depressor nerves thereby permitting increased activity of the vasoconstrictor nerves. However when the circulating blood volume is reduced beyond a certain point the blood pressure remains low and the combined factors of reduced circulating volume, low pressure and vasoconstriction predispose to shock.

Noceptive stimuli from the traumatized regions have been held to lower blood pressure and produce shock without precise statement as to the structures acted on by the stimuli (6).

Page has reported the appearance of a vasoconstrictor substance in the blood during shock

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induced by trauma, hemorrhage and burns and considers this a factor in the production of the vasoconstriction.

Another theory advanced by Freeman (7) and Cannon on the basis of animal experiments is that shock may be initiated in the presence of a normal blood volume by fright and pain or other great emotional excitement which cause hyperactivity of the sympathoadrenal system with pronounced and extensive vasoconstriction except in the heart and skeletal muscles. Their theory is that vasoconstriction is at once a protecting and a damaging response protecting in that it maintains the circulating blood volume for the vital centers and damaging in that it decreases nourishment of the tissues of the body in general and thus causes peripheral capillary damage loss of plasma into the tissues fall of blood pressure and shock. Vasoconstriction precipitated by painful impulses from the injured field or by emotional states in the higher centers during emotional states of fright and stress constitutes a specific application of the emergency function of adrenalin described by Cannon. Freeman has also reported that because of loss of vasoconstriction sympathetomized animals were protected from shock due to hemorrhage.

These authors reported no clinical cases of shock initiated by acute hypertension as evidence of increased vasoconstriction which would be expected in the earlier stages before the onset of low blood pressure and other manifestations of the shock syndrome. Nor has it been possible to find any report of such cases in the literature since the theory was advanced.

Other experimental studies have failed to support the theory of Freeman and Cannon. Prohaska, Harms and Dragstedt administered adrenalin to unanesthetized dogs continuously over periods as long as weeks in doses much

TABLE I.—CHANGES OBSERVED IN THE BLOOD PRESSURE, HEMATOCRIT AND HEMOGLOBIN OF 8 DOGS WITH PROPRIOCEPTOR DEPRESSOR NEUROTOMY

Dog No.	Before proprioceptor depressor neurotomy			After proprioceptor depressor neurotomy		
	Blood pressure mm. Hg.	Hemato- crit per cent.	Hemo- globin gm./100 cc.	Blood pressure mm. Hg.	Hemato- crit per cent.	Hemo- globin gm./100 cc.
541	55	7		30	54	
141	90		6	90	26	16.8
44		54	18	20	37	20
5	106	28	8	200	33	99
	30	42	6	6		
730	160	47		190	33	
73	24	30		74	5	8
75	28	17		260	33	
Average	57	47	16.6	64	3	7.9

The values in columns 1, 2, and 3 were obtained before and those in the last three columns, immediately after recovery from anesthesia (saccharose crystal—20 mgm./kgm. of body weight).

larger than those given by Freeman for a few hours which maintained the animals in moderate hypertension without the production of shock. The adrenalin produced death by inhibition of gastrointestinal motility and derangement of carbohydrate metabolism. Hamlin and Gregersen criticized the work of Freeman because of the large amount of adrenalin administered, the inaccuracy of the method of plasma volume determination, and their own failure to find in cats a reduction in plasma volume and shock after adrenalin administration at a rate four times that found by Cannon in response to afferent nerve stimulation. This was true both for normal and sympathectomized animals under both nembutal and local anesthesia. Wiggers found fault with the theory for the following reasons: (1) It has not been demonstrated that the total resistance to outflow from the aorta is increased by early shock. (2) Experimental hypertension produced by the Goldblatt method and clinical hypertension in both of which total peripheral resistance is increased do not cause shock. (3) Shock is not produced in experimental animals by prolonged stimulation of the sympathetics. (4) A dose of adrenalin large enough to cause

shock damages the heart and the pulmonary circulation. (5) Vasoconstriction of the spleen throws out more blood into the circulation and tends to prevent shock. He concludes by stating that vasoconstriction in shock is a helpful rather than a harmful state.

That Freeman has rejected the theory for man is shown by his recent report with Freeman and Miller (8) on shock production in unanesthetized dogs by prolonged continuous injection of adrenalin which states 'there is no evidence that clinical shock in humans is a result of overproduction of adrenalin.'

Both experimental and clinical studies have been carried out in an attempt to test the validity of the sympathoadrenal theory of shock.

PART I.—HYPERACTIVITY OF VASOCONSTRICTOR IMPULSES AS A CAUSE OF SHOCK TESTED EXPERIMENTALLY BY SECTION OF THE AORTIC DEPRESSOR AND CAROTID SINUS PROPRIOCEPTIVE NERVES (PROPRIOCEPTOR DEPRESSOR NEUROTOMY)

One of the most intense and prolonged vasoconstrictions that it is possible to produce experimentally is that observed following section of the aortic depressor and carotid sinus proprioceptive nerves. Excision of the carotid sinuses has been found to destroy more completely the carotid sinus efferent branches than attempts to section all of the carotid sinus nerve branches (Heymans et al.). With these depressor pathways ablated the animal is constantly subjected to overactivity of a reflex which ordinarily causes vasoconstriction whenever the systemic blood pressure is lowered. This increased vasoconstriction is evidenced in these animals by a marked hypertension occasionally measuring over 300 millimeters of mercury and can be experimentally demonstrated by the presence of a high resistance to perfusion of the radicles of distribution of a severed artery. Heymans reported an increased output of adrenalin by such animals. However Trendelenburg tests on toads with blood from hypertensive dogs of this series of experiments failed to reveal a positive test for hyperadrenalemia. It would appear that if hyperactivity of the sympathoadrenal system is of importance in the causation or aggravation of shock, normal animals made hypertensive by

section of the aortic depressor and carotid sinus proprioceptive nerves would be predisposed to shock and surviving animals might withstand shock due to hemorrhage less well than normal animals. Experiments to test the first point were carried out as follows.

The technique for depressor nerve ablation is that originally described by Heymans and has been repeatedly used successfully in this laboratory by Grimson and the author (16) in the past 4 years. The operation is carried out under light ether anesthesia with morphine and atropine premedication and recently we have used intravenous evipal. The neck is opened in the midline through a generous incision centered slightly below the thyroid bone. By blunt dissection the carotid sheaths are exposed bilaterally. Usually the right sheath is opened first and the vagosympathetic trunk brought into view with as little disturbance of normal relationships as possible. The trunk is then dissected and the central shiny white compact core of vagal fibers identified. This vagal core is preserved and a 2 centimeter length of the remaining portion of the vagosympathetic trunk excised. The right common carotid artery and at least 2 centimeters of the internal carotid and the external carotid and its branches are mobilized. Ligatures are then placed about the latter vessels near the skull and tied. The common carotid artery is also excised. This resection thus includes the internal external and common carotid arteries the carotid bifurcation the carotid sinus and the carotid sinus nerves. On the left side the procedure is carried out as described except that a 2 centimeter segment of the entire vagus trunk, including the cervical sympathetic chain and aortic depressor nerves is excised. The skin is then closed.

Soon after this operation the dog's mean arterial blood pressure as measured by needle puncture and mercury manometer is often elevated to 200 millimeters of mercury but frequently it returns in a few minutes to the vicinity of the previous level only to become elevated after the animal has recovered from the acute effects of the operation. Table I indicates the blood pressure records of 8 dogs recently subjected to proprioceptor depressor

TABLE II.—CHANGES OBSERVED IN THE BLOOD PRESSURE, HEMATOCRIT AND HEMOGLOBIN OF AN 8.6 KILOGRAM MALE DOG WITH PROPRIOCEPTOR DEPRESSOR NEUROTOMY

Dog No. 47			
Date	Blood pressure mm. Hg.	Hematocrit per cent	Hemoglobin gm. / 100
Control	50	43	5.6
2/30—Proprioceptor depressor neurotomy			
/	50	43	
/	4	37	5.4
7/2/5	80	34	4
7/2/5	80	33	8
7/2/5	30	33	3
7/2/5	90	33	3.5
7/2/5	144	33	4.8
7/2/5	136	34	4
/		43	4

neurotomy and Table II indicates in more detail the record of one of these dogs over a period of 41 days. Blood pressure readings on a given dog may vary by as much as 60 millimeters between extremes but all readings are at an increased level almost always above 200 millimeters and usually above 250 millimeters of mercury. For the past 2 years we have observed an animal with a blood pressure consistently in excess of 300 millimeters of mercury and readings as high as 340 millimeters have been obtained with the animal conditioned to lie on its back and only gently restrained. Characteristically these animals present no untoward symptoms and as yet have not been observed to develop signs comparable to those seen in the late stages of experimental hypertension produced by the Goldblatt method. To date complete paravertebral sympathectomy has been found to be an effective means of lowering the blood pressure of these animals for prolonged periods. However there is a tendency for a gradual progressive elevation of blood pressure but usually not to levels in excess of 200 millimeters of mercury. This late rise observed months after operation is presumably due to re-establishment of sympathetic function. With improvement in operative technique and more experience with the operation the mortality rate early and late has progressively

TABLE III.—BLOOD PRESSURE CHANGES OBSERVED IN 27 DOGS WITH LONG STANDING HYPERTENSION FOLLOWING PROPRIOCEPTOR DEPRESSOR NEUROTOMY

Dog No	Blood pressure (mm Hg)			Duration of hypertension (months)	
	Before depressor nerve section	Range during chronic period	Average during chronic period	Living	Sacrificed
678	143	100-160	120		
598	143	100-140	130	14	
196	36	30-120	124	23	
857	42	100-140	124	24	
395	30	90-115	103		6
1	26	30-100	61		
399	138	100-155	103		7
497*	10	↑	10		
497*	70	30-100	112		
394	30	↑	140		
393*	100	100-104	112		
497*	34	100-115	108		16
497*	36	170-170	174		
433*	143	80-160			
723	33	2-100	30		
139	16	10-175	157		8
49	123	80-134	90		6
	123	100-102	100		
43	123	100-100	87		
	11	100-100			5
	147	80-100			5
806	69	170-174	104		
433†	68	140-150	10		10
433†	58	100-100	34		16
823		120-10	64		16
497†	58	110-134	103		
344	120	110-138	110		14
Average	60	100-154	107		

(*)-Lact in Group I (†)-Lact in Group III (†)-Less than 2 readings of blood pressure.

fallen. An occasional animal has died on the operating table of what appeared to be reflex arrest of heart action or of respiration during dissection or manipulation in the region of the carotid sinus or carotid sinus nerves. Death was instantaneous and on only two occasions was cardiorespiratory activity restored by artificial respiration administration of stimulants, and the generous use of intravenous fluids. A few of the dogs died in the first 3 or 4

postoperative days with inability to take food and water and with persistent vomiting and loss of weight. This complication is similar to the course seen following double vagotomy and of course in this operation the great majority of the vagal fibers are transected. In a series of 10 dogs operated on consecutively only 1 died on the 6th postoperative day after persistent vomiting and progressive loss of weight. Not all of the animals which survive the operation develop hypertension presumably due to the fact that all of the depressor fibers in the vagus are not sectioned. At no time have we observed a protracted vasodilation with the signs and symptoms of surgical shock. Table III contains the pressure changes observed in 27 dogs subjected to proprioceptor depressor neurotomy. Their blood pressures before operation ranged from 120 to 170 millimeters of mercury with a general average of 140 millimeters of mercury. During the chronic period of observation, their average range of fluctuation was from 104 to 154 millimeters of mercury with an average for all animals during the chronic period of 107 millimeters of mercury.

PART II.—THE EFFECT OF GRADED HEMORRHAGE ON ANIMALS WITH CHRONIC VASOCONSTRICTOR HYPERACTIVITY PRODUCED BY PROPRIOCEPTOR DEPRESSOR NEUROTOMY

Young healthy dogs were used which all had been under observation for periods ranging from 4 months to 2½ years. Twelve dogs had been subjected to proprioceptor depressor neurotomy from 6 weeks to 28 months before the time of acute experimentation. Two dogs had had complete paravertebral sympathectomy done 16 and 18 months previously. Five dogs had had no previous surgery and were used as controls.

Plasma volume determinations were made on each animal before experimentation was begun. For this purpose dilution curves of the blue dye T 1824 were utilized. Dye concentrations were measured in serum samples by means of the Evelyn photoelectric microcolorimeter. Control hematocrit and hemoglobin readings were also made. The Van Allen hematocrit was utilized because of the small volume of blood required for the determination. He-

hemoglobin levels were measured by means of the Evelyn photoelectric macrocolorimeter. In each case a control mean arterial blood pressure reading was made by direct needle puncture of the femoral artery the needle being attached to a Kaufman syringe connected to a mercury manometer. Total blood volume was calculated from the plasma volume and the hematocrit using the formula: total blood volume equals the plasma volume divided by one hundred minus the hematocrit. Most of the animals with chronic hypertension used in these tests had had frequent blood volume and blood pressure readings before the time of acute experimentation and in each case the determination made at the beginning of the acute experiment was not significantly different than those previously recorded.

The animals were classified into 4 groups: Group I—5 dogs with long standing proprioceptor depressor neurotomy tested under local anesthesia; Group II—5 normal dogs tested under local anesthesia; Group III—7 dogs with proprioceptor depressor neurotomy tested under chloralose anesthesia; Group IV—2

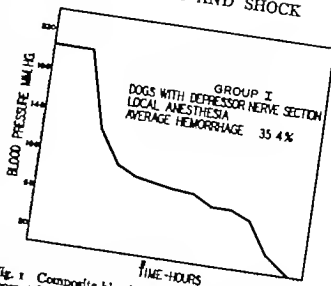


Fig. 1. Composite blood pressure curve of 5 chronically vasoconstricted dogs subjected to graded hemorrhage.

dogs with complete paravertebral sympathectomy tested under chloralose anesthesia.

RESULTS

Group I These 5 chronically vasoconstricted animals were all subjected to the following program of graded hemorrhage: First under procaine infiltration anesthesia the femoral

TABLE IV—EFFECT OF GRADED HEMORRHAGE ON 5 DOGS WITH LONG STANDING NEUROGENIC HYPERTENSION, Group I.—Dogs with depressor nerve section—local anesthesia

Dog No.	Weight (kgm.)	Blood pressure (mm. Hg.)				Duration of chronic hypertension (months)
		Before depressor nerve section	Average during chronic period	At beginning of acute experiment		
18	15.5	118	120	120		23
17	9.4	118	134	120		23
16	9	111	118	120		6
3		118	118	120		12
14	11.7	118	118	120		14
Averages		115	117	120		

Dog No. (cont.)	Total blood volume	Anatomic blood		Hematocrit (per cent)		Hemoglobin gms / 100 c.		Survival after onset of bleeding (minutes)
		% vol. by dye method	% vol. by body weight	Initial	Terminal	Initial	Terminal	
8	690	56	57	46	35	9	5.6	31
7	945	55.4	57.5	46	45	0	5.6	510
6	61	51.3	57.5	47	45	6.0	5	570
5	10	53.0	55	55	40	7.7	1.7	5
14	1010	48.6	51.5	50	30	7.0	0.8	450
Averages		51.4	57	50	44	7.4		240

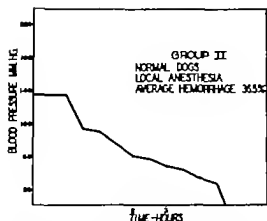


Fig. Composite blood pressure curve of 5 normal dogs subjected to graded hemorrhage.

arteries were exposed. At one-half hour intervals a sample of 1 cubic centimeter of blood for hematocrit and hemoglobin determinations was drawn from one femoral artery and mean arterial blood pressure measurement then made by connecting a mercury manometer to the needle used for obtaining the blood sample. Following this the animal was bled at half hour intervals from the opposite artery according to the method of Evans (2). At beginning of experiment—10 per cent of blood volume as measured by dye method, 30 minutes after first bleeding, 5 per cent of blood volume, 60 minutes after first bleeding, 2½ per cent of blood volume, and 2½ per cent of blood volume each half hour thereafter until death occurred.

As indicated in Table IV these animals weighed from 9.4 to 19.2 kilograms and had had sustained vasoconstrictor hyperactivity

for from 14 to 28 months. Their blood pressures ranged from 103 to 234 millimeters and averaged 217 millimeters of mercury. 80 millimeters higher than their normal average of 138 millimeters. Their total blood volumes varied from 945 to 1690 cubic centimeters, their hematocrits from 50 to 66 per cent, and their hemoglobins from 16.6 to 19.2 grams per 100 cubic centimeters. They survived bleeding of amounts ranging from 354 to 523 cubic centimeters or from 27.2 to 45.0 per cent of their measured blood volume. Using a figure for estimated total blood volume of 10 per cent of the body weight, they were bled from 27.0 to 37 per cent of their volume as calculated by this method. They survived bleeding of an average of 35.4 per cent of their total blood volume as determined by dye dilution measurement or 33.5 per cent of their total blood volume on the basis of body weight. The period of survival varied from 270 to 480 minutes, with an average of 340 minutes. In each animal hemodilution was observed, the hematocrit falling from 5 to 20 per cent with an average of 12 per cent, and the hemoglobin falling from 19 to 7.7 grams per 100 cubic centimeters, with an average of 4.1 grams per 100 cubic centimeters. As seen from the composite graph (Fig. 1) the blood pressure fell sharply early in the course of bleeding and then only slightly during the major portion of the period of hemorrhage, the decline becoming more precipitous in the hour before death.

Group II. These 5 normal control animals were subjected to the same experimental procedure as outlined for Group I. As indicated in Figure 6 they weighed from 8.2 to 12.2 kilo-

TABLE V.—EFFECT OF GRADED HEMORRHAGE ON 5 NORMAL DOGS. Group II—Normal dogs—local anesthesia

Dog No.	Weight (kg.)	Blood pressure	Total blood volume c.	Amount bled			Hematocrit (per cent.)		Hemoglobin gm./100 c.		Survival after onset of bleeding (minutes)
				c.	% vol. by dye method	% vol. by body weight	Initial	Terminal	Initial	Terminal	
120	9	70	1070	510	30	36	27	40	9.5	16	415
121		100	850	344	41	36.5	30	36	7.4	12	130
122	8	40	820	189		23	44		5		20
123		145	895	269	30	28	31	46	19.5	19.5	5
124	8	30	960	360	37.5	40.5	40	30	14.6		2.5
Average		59			35.8	31.6	32	41	17.9	14.8	165

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grams and their blood pressure ranged from 120 to 140 millimeters of mercury. Their total blood volumes varied from 810 to 1020 cubic centimeters their hematocrits from 44 to 57 per cent and their hemoglobin from 14.6 to 19.5 grams per 100 cubic centimeters. They survived bleeding of amounts ranging from 189 to 510 cubic centimeters or from 22.5 to 50 per cent of their measured total blood volume. Using a normal figure for total blood volume of 10 per cent of the body weight they were bled from 22.0 to 56 per cent of their volume on this basis. They survived bleeding of an average of 36.5 per cent of their total blood volume as determined by dye dilution measurement or 35.6 per cent on the basis of body weight. The period of survival varied from 120 to 435 minutes with an average of 285 minutes. In 4 animals hemodilution was observed the hematocrit falling from 8 to 14

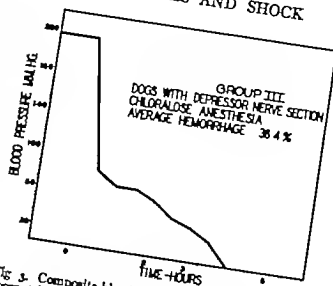


Fig. 3. Composite blood pressure curve of 7 chronically vasoconstricted dogs subjected to graded hemorrhage.

TABLE VI.—EFFECT OF GRADED HEMORRHAGE ON 7 DOGS WITH LONG STANDING NEUROGENIC HYPERTENSION Group III—Dogs with depressor nerve section—chloralose anesthesia

Dog No.	Weight (kgm.)	Blood pressure (mm. Hg.)			Duration of chronic hypertension (months)
		Before depressor nerve section	Average during chronic period	At beginning of acute experiment	
13	20	140			
21	4	80	55	30*	
227	13.3	70			
196B	3.0	34	84.3	140*	1
196A	3.0	35	80.6	140*	1
193	14.7	140	970	30*	
20	2.5	40	850	120*	15
Averages		4	247	20*	
				10*	
				14*	

Dog N (cont.)	Total blood volume c.	Amount bled			Hematocrit (per cent)		Hemoglobin gms / 100 c.c.		Survival after onset of bleeding (minutes)
		c.	% vol. by dye method	% vol. by body weight	Initial	Terminal	Initial	Terminal	
5	1030	300	30	3	53	46	11	6.4	285
27	1130	375	40	35	53	46	11	7.6	180
196B	300	408	35	30.5	55	46	11	7.6	20
196A	260	510	40	32.5	55	44	11.3	5.5	340
93	1030	725	60	34.5	53	44	11.3	5.5	70
21	870	306	30.0	1.0	5	51	8	7.5	220
Averages		62	80.0	18.5	51	53	17.5	6.4	
*Dog anesthetized			26.4	22.0	53	48	17.5	6.0	

*Dog anesthetized

TABLE VII.—EFFECT OF GRADED HEMORRHAGE ON 2 SYMPATHECTOMIZED DOGS, Group IV—
Sympathectomized dogs—chloralose anesthesia

Dog No	Weight (kgm.)	Blood Pressure (mm. Hg.)			Duration of chronic hypotension (months)
		Before sympathectomy	Average during chronic period	At beginning of acute experiment	
808	8	90	133	90*	6
890	16.7	120	13	90*	3
Averages		90	3	190*	17

Dog No (cont.)	Total blood volume	Anesthetized blood			Hematocrit (per cent)		Hemoglobin gms./100 c.c.		Survived after onset of bleeding (minutes)
			C ¹⁴ vol. by dye method	C ¹⁴ vol. by body weight	Initial	Terminal	Initial	Terminal	
802	945	270	90	90	48	5	3	16	120
899	195	350	30		43	41	5.3	4.9	120
Averages			15	95	45	41	1.3	1	120

Dog anesthetized

to 53 per cent and in hemoglobin from 15.5 to 17.9 grams per 100 cubic centimeters. Thus for the entire group there was an average decrease in hematocrit of 6.5 per cent and in hemoglobin of 2.5 grams per 100 cubic centimeters. As seen from the composite graph (Fig. 2) the blood pressure maintained a more steady rate of decline throughout the entire experiment than was the case in Group I (Fig. 1) with less sharp initial and terminal periods of decline.

Group III These 7 chronically vasoconstricted animals were subjected to a somewhat different experimental procedure than that used for the preceding two groups. After control blood volume, blood pressure, hematocrit and hemoglobin readings had been made the animals were anesthetized by means of chloralose, 100 milligrams per kilogram of body weight given intravenously in aqueous solution. Continuous blood pressure recordings were made on a smoked drum, heparin being used in the cannula as an anticoagulant. From the opposite femoral artery the animals were then bled at the rate of 10 per cent of their blood volume each 10 minutes until a blood pressure of 70 millimeters of mercury was reached and maintained. The blood volume figure used as the basis for this calculation was obtained by dye measurement before anesthesia. If an animal recovered a blood pressure of more than 70 millimeters of mercury later in the experiment, there was an additional bleed-

ing of 5 or 10 per cent of the blood volume depending on the response to bleeding at that time. Three of the 7 dogs were each once subjected to an additional bleeding for this reason.

As indicated in Table VI these animals weighed from 8.3 to 15.9 kilograms and had had sustained vasoconstrictor hyperactivity for from 6 weeks to 25 months. Their blood pressures ranged from 206 to 270 millimeters and averaged 247 millimeters over 100 millimeters higher than their normal average of 141 millimeters of mercury. Under anesthesia their pressures ranged from 150 to 240 millimeters, averaging 214 millimeters, 75 millimeters higher than their normal average. Their total blood volumes varied from 810 to 1,300 cubic centimeters; their hematocrits from 50 to 56 per cent and their hemoglobin from 15.9 to 19.2 grams per 100 cubic centimeters. They survived bleeding of amounts ranging from 162 to 756 cubic centimeters, or from 20.0 to 60.0 per cent of their measured total blood volume or from 19.5 to 54.5 per cent of their volume estimated from body weight. They survived bleeding of an average of 36.4 per cent of their total blood volume as determined by dye dilution measurement of 31.0 per cent of their total blood volume on the basis of body weight. The period of survival varied from 120 to 340 minutes, with an average of 240 minutes. In all but 1 animal a blood dilution was observed, the hematocrit falling from

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1 to 10 per cent and the hemoglobin falling from 0.5 to 3.2 grams per 100 cubic centimeters. One animal exhibited a rise in hematocrit from 52 to 53 per cent. Thus for the entire group there was an average decrease in hematocrit of 5 per cent and in hemoglobin of 2 grams per 100 cubic centimeters. As seen from the composite graph (Fig. 3) the blood pressure fell sharply during the short period of bleeding and then continued in a fairly rapid decline until death.

Group IV Two sympathectomized animals were subjected to the same experimental procedure outlined for Group III. As indicated in Table VII they weighed 12.8 and 16.7 kilograms and the blood pressure of both during the chronic period was 132 millimeters and 110 millimeters of mercury. Their total blood volumes were 925 and 1195 cubic centimeters; their hematocrits 46 and 45 per cent and their hemoglobin 15.3 grams per 100 cubic centimeters. They survived bleeding of 370 and 399 cubic centimeters or 40 and 30 per cent of their measured blood volume respectively. They were bled 29.0 and 21.5 per cent of their volume on the basis of body weight. They survived bleeding of an average of 35.0 per cent of their total blood volume as determined by dye dilution measurement or 25.0 per cent of their total blood volume as calculated on the basis of body weight. They survived with an average survival period of 230 minutes. No changes of significance were noted in their hematocrit and hemoglobin readings during the course of the experiment. As seen from the composite graph (Fig. 4) their blood pressure went into a rather sharp steady decline from the time of onset of bleeding until death.

PART III — HYPERACTIVITY OF THE SYMPATHO-ADRENAL MECHANISM AS A CAUSE OF SHOCK EVALUATED BY A REVIEW OF CLINICAL CASES

If hyperactivity of the sympathoadrenal system is of importance as a primary etiological factor in shock or if it plays a rôle in predisposition to shock due to other primary causes, one might expect to obtain some supporting

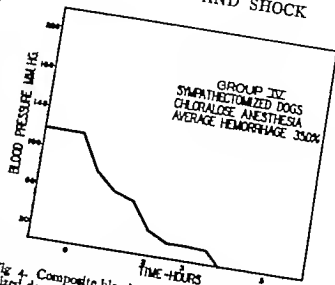


Fig. 4. Composite blood pressure curve of 2 sympathectomized dogs subjected to graded hemorrhage.

evidence such as elevated blood pressure before the onset of shock by a review of selected clinical cases.

First in a consideration of shock following accidental injury in otherwise healthy persons the impressive feature of cases admitted to the University of Chicago Clinics has been the loss of whole blood either externally or into body cavities or tissues or the loss of blood and plasma into the traumatized tissues. The signs of vasoconstriction as evidenced by pallor, rapid pulse, poorly filled veins and scanty bleeding on skin puncture are usually present but only after the blood volume has been reduced. If increased vasoconstriction initiated by pain and fright were the primary etiological factor patients presenting this alteration without reduction of circulatory blood volume should exhibit a hypertension before the onset of shock. There is however practically no concrete evidence for this to be found in the literature. Grant and Reeve reported 100 London air raid casualties studied carefully but for very brief periods. Sixty three patients had blood pressures under 100 millimeters of mercury and all had had severe hemorrhage. Twenty-eight had had blood pressures ranging between 100 and 140 millimeters of mercury with a record of hemorrhage as follows: little or none 3, moderate 3, severe 18 and unknown 4. Nine patients had blood pressures of 140 millimeters of mercury or above and the record of hemorrhage was as follows: little or none 7, moderate 1, severe 1. The ages were as

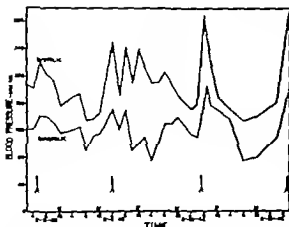


Fig. 5. Four day blood pressure record of a 35 year old female with medullary tumor (pheochromocytoma) of the right adrenal gland. Four distinct clinical attacks of paroxysmal hypertension occurred at points marked A.

follows: 20 to 29 three, 30 to 49 two, over 50 four. Some of the subjects were already hypertensive while others falling in the younger age groups seemed to have had an elevation of blood pressure as a reaction to injury. The number for each group was not stated. The pulse rates on admission ranged from 64 to 92. The injuries varied from multiple minor wounds with little or no hemorrhage to severe wounds and hemorrhage. In some the blood pressure fell to normal within a few hours but in others it remained high for at least 1 or 2 days. All cases underwent operation without collapse and all survived the short periods of observation. Their clinical study lends little support to the theory that shock may be produced by pain and fright exciting hyperactivity of the sympathoadrenal system.

A study was made of 44 subjects admitted to these clinics with fresh, major, accidental injuries all of which caused pain and many of which were associated with fright. These patients had all sustained fractures of at least one of the following bones: femur, tibia, pelvis, spine, skull, and in many cases multiple fractures or considerable somatic and visceral soft tissue injuries were also present. Twenty-four of these patients had fractures of one or both femora and of these 3 were in shock at the time of admission to the hospital. 8 had fractures of one or both tibiae and fibulae, none with shock, 9 had fractures of the skull, one

with shock, and 4 had fractures of the pelvis, 3 of whom were in shock on admission or shortly thereafter. The majority of the patients reached the hospital within a hour after injury. Of the 7 patients who developed shock, 6 were admitted with blood pressures as follows: 90/50, 96/58, 85/70, 84/56, 86/60, and 1 was not obtainable. One 62 year old female had a pressure of 140/88 on admission which fell to 80/60 3 hours later when she was in shock. Hypertension was not observed in the entire series either early or late.

What has been said of hypertension in accident cases holds also in general for patients without previous circulatory disturbance who undergo operation for conditions other than acute injury. Observations by our anesthetists of patients who were recognized as being frightened when they came to operation have shown that while the pulse may be accelerated the blood pressure just before starting the anesthesia is usually unchanged, sometimes reduced and very rarely elevated. Patients with thyrotoxicosis regularly display some degree of cardiac embarrassment and not infrequently present with hypertension or advanced cardiac disease. In the 4 year period ending February 1, 1943, 198 thyrotoxic patients were subjected to subtotal thyroidectomy in this clinic, after preparation by rest, sedation and iodine therapy. One patient died as a result of extensive blood loss and prolonged operation. None of the others went into shock although many had temporary elevations of blood pressure before, during or after operation and a few patients with blood loss had a fall of blood pressure and received transfusions either during or after operation for the prevention of shock.

Next, in reviewing 567 consecutive cases of chronic hypertension subjected to major or minor operations other than sympathectomy in this clinic from February 1, 1939 to February 1, 1943, it was found that no case was recorded as having developed shock. However, many of them had blood transfusions during and after operations accompanied by blood loss and without this replacement therapy shock might have developed. Eighteen patients underwent extensive sympathectomy for hypertension and marked lowering of blood

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pressure resulted with supervision of shock in some cases

Lastly patients with endocrine tumors of the medulla of the adrenal gland (pheochromocytomas) frequently have bouts of paroxysmal hypertension presumably due to the liberation of a pressor substance from the tumor into the blood stream. The attack is usually characterized by a pounding headache dyspnea orthopnea palpitation nausea vomiting and weakness. But the blood pressure is always elevated during the attack and declines to approximately the previous level on subsidence of the paroxysm and hypotension with shock is rarely if ever a sequel in attacks not associated with operations or major accidents. Figure 5 represents the blood pressure of one such patient observed in this clinic for a period of 4 days during which time 4 definite bouts of paroxysmal hypertension occurred but without the development of shock. However when these patients are operated on for the removal of the tumor they usually develop hypertension and a state of surgical shock may follow. Three patients operated on in this clinic all had hypertension during operation. There was sufficient circulatory embarrassment from the paroxysm and blood loss to warrant blood transfusion in 2 cases but shock developed in none of them.

Biskin, Mayer and Bradner reviewed a selected group of 20 cases 15 of which were reported to show some degree of shock during and immediately following operation. In 15 cases it was severe. The recent review of Hyman and Mencher with a report of 2 additional cases brought the world's literature of patients operated upon up to 35. There were 14 operative deaths in all of which shock played a role. The blood pressure is prone to rise to a high level as the operation proceeds and to decline precipitously following removal of the tumor. (See reaching shock level of 100/100 mm. Hg. in 10 minutes.) Mayer and Bradner state that the withdrawal of epinephrine or related pressor substance from arteries given access to the blood stream causes these materials to be given to the blood stream by the sympathetic system which causes plasma

leakage and reduction of the circulating blood volume. The usual occurrence of the decline in pressure immediately following rather than before the removal of the tumor speaks against this theory. Also adrenalin has been reported to be beneficial in combatting the low blood pressure which should not be the case were capillary damage and plasma loss from sympathoadrenal overactivity the cause in the first place. Although the pressor substances entering the blood stream during operation for removal of a pheochromocytoma do damage to the circulation and predispose to shock there is no evidence that a comparable amount of such substances is ever put out by the normal adrenals of an injured person not harboring such a tumor. That injury may precipitate grave circulatory embarrassment in a person with a pheochromocytoma is illustrated by the following case.

C. A., a 54 year old female entered the hospital 24 hours after falling on ice striking her left hip. She experienced pain in the left hip and was unable to move her left lower extremity. Twelve hours before admission she became nauseated and vomited. Physical examination at the time of admission revealed that the patient was in acute distress with pain on motion of the left lower extremity which lay in a position of marked external rotation. She was restless pale cold and clammy dyspneic and perspiring profusely. Blood pressure was 268/110 pulse 60 temperature 98.0 degrees F. red blood cells 6.55 million white blood cells 11,600. Urine was acid in reaction with specific gravity 1.030, +++ albumin with many bacteria occasional red blood cells and white blood cells and a few granular cells and casts. X ray films revealed an incomplete fracture of the left femoral neck with some rotation. Shortly after admission the patient's temperature rose to 100.7 degrees F. the pulse rate increased to 150 with extrasystoles and the blood pressure gradually fell. Death occurred 12 hours after admission. At postmortem examination a pheochromocytoma of the right adrenal gland was found and on analysis contained 100 milligrams of adrenalin. This patient had been in excellent health before the accident and had not consulted a physician for many years so no record of previous blood pressures was obtained.

Summary

In Part I of this paper an operative procedure was described which is capable of producing in the dog a permanent state of marked vascular motor hyperactivity that is altered a little or none by administering a (Table VI). In r

instance in more than 70 operations of this sort, performed in this laboratory have the signs or symptoms of surgical shock been encountered. Hypertensive animals have been followed for periods in excess of 2 years without presenting the signs or symptoms of shock.

In Part II animals with long standing vasoconstrictor hyperactivity have been subjected to graded hemorrhage and their responses compared with those of similar bleedings in a group of normal dogs. Under the conditions of the experiment described here 5 normal dogs were found to tolerate an average loss of 36.5 per cent of their total blood volume as calculated by the dye dilution method before death resulted and to live for an average of 285 minutes after the onset of intermittent bleeding by the method of Evans (2). Twelve dogs previously subjected to proprioceptor depressor neurotomy when subjected to graded hemorrhage were found to die after an average loss of 35.9 per cent of their total blood volume and to live for an average of 190 minutes after the onset of bleeding.

Further as outlined in Part III from experience with injuries and operations in this clinic there is no basis for the belief that hyperactivity of the sympathoadrenal system is of importance in causing or predisposing to shock except when the patients harbored pheochromocytomas.

CONCLUSIONS

1. Twenty-seven dogs have been subjected to aortic depressor and carotid sinus proprioceptor nerve section which resulted in marked vasoconstrictor hyperactivity with hypertension without the production of shock either early or late.

2. Twelve of these animals with long standing vasoconstrictor hyperactivity tolerated hemorrhage in approximately the same manner as did five normal dogs. Seven of these showed no significant change of blood pressure under a general anesthetic chloralose.

3. The experience of this surgical clinic lends no support to the theory of sympathoadrenal hyperactivity as a cause of shock complicating injury or operation except that operation on or injury of a patient with pheochromocytoma may predispose to shock.

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RENAL AGENESIA

A Study of Thirty Cases

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UNILATERAL renal agenesis is a problem of increasing clinical importance. The statement has been made that it matters little from a clinical standpoint whether a patient has a congenital absence of one kidney or an under development with little or no function. This is true as far as surgery upon the functioning kidney is concerned. However the prognosis for health may be different with the two conditions.

The differential diagnosis of renal agenesis, aplasia, hypoplasia and pylonephritic contraction becomes more important with the realization that an aplastic kidney or a blind ureter may cause pain (7 11 17) a hypoplastic kidney may be subject to recurrent infections and an atrophic kidney may cause hypertension. The clinical diagnosis of renal agenesis is seldom made with assurance. One object of this study was to try to establish criteria that might simplify and secure the diagnosis.

The study of the embryology of renal agenesis and associated developmental defects is very interesting. Certain phases of the subject have not been emphasized sufficiently. The present paper deals primarily with renal agenesis, studies of renal aplasia and hypoplasia will be reported elsewhere.

Definition The literature is confused by the failure of many authors to distinguish properly between renal agenesis and aplasia. It is important that the distinction be made. Agenesis denotes the complete lack of development of the metanephros on one or both sides. The presence of a vestige of renal tissue should classify a case as one of aplasia, not agenesis. Another differentiation that must be made is between the absence of a kidney on one side due to agenesis and that due to crossed ectopia. The latter condition is often termed

'solitary kidney' this leads to further confusion. The proper descriptive title should be applied. If there is evidence that the kidney tissue present on only one side developed from the renal blastema of both sides the condition is one of crossed ectopia, not of unilateral agenesis. In such a case there will be a ureter opening into each side of the trigone.

Embryology The kidney is formed from a cap of mesoderm the metanephric blastema about the ureteral bud. The differentiation of this nephrogenic blastema begins with the growth of the ureteral bud into it. The latter sprouts from the dorsal surface of the wolffian duct near the cloaca during the fourth week (4 5 to 5 3 mm greatest length) of fetal growth.

Nicholson and others have noted that no instance of a solid or cystic mass suggestive of persistent renal anlage in the absence of a ureter has been described. (Such a case is to be reported elsewhere with a study of renal aplasia.) It also has been stated commonly that without the development of a ureter the renal anlage fails to form. This is not strictly true. Brown has demonstrated in mice that the nephrogenic blastema develops and indeed assumes the form of the embryonic kidney in the complete absence of a ureter due to experimental arrest of the wolffian duct. Boyden produced the same result in chicks. It was not determined what the eventual fate of the kidney tissue was in these animals. In the oldest it was fading. Boyden also described a human embryo of 10 millimeters greatest length in which there was a failure of development of the ureter as a result of arrested growth of the wolffian duct. In this specimen the renal anlage had formed on the side of the absent ureter. Tubular differentiation which is dependent upon the fusion of the ureter with the blastema. Mere contact of the two in mice induces rudimentary tubule

formation whereas, for complete development, normal fusion is necessary (3)

Another embryological fact of interest and importance with respect to the interpretation of maldevelopment of the kidney is the vascularization of the organ. The renal veins do not form until the kidney has reached its adult position 22 millimeters greatest length stage of growth (14). The metanephric artery becomes distinguished from the other mesonephric arteries at about this same stage of development (8).

The upper pole of the kidney comes in contact with the suprarenal gland at about the 18 millimeter stage of growth. While the cortex of the gland and the renal anlage arise in the same region the development of the two organs is entirely independent.

Etiology The fundamental cause of renal agenesis is probably to be found in most cases in defective germ plasma. In support of this theory the report of Madison (13) of the occurrence of bilateral agenesis in two children of the same mother is usually cited. The common concurrence of widespread developmental defects suggests more than a local cause. Abnormal pressure due to oligohydramnios and other causes can account for few of these dysplasias.

The actual mechanism of development is variable. Cases described here and elsewhere indicate this. The findings of Boyden and of Brown mean that in the strict sense of the word actual renal agenesis is very rare and can result only from failure of the metanephric blastema to develop. In all other cases the renal anlage has formed and undergone resorption. Resorption always follows failure of the ureter to come in contact with the nephrogenic cap.¹ If contact occurs but proper fusion fails to take place aplasia usually results. Failure of contact between the ureter and nephrogenic cap most often results from ureteral agenesis or maldevelopment. This in turn may be caused by failure or arrest of development of the pronephros, the pronephric duct, the mesonephros or the ureteral bud itself.

¹The instances of the persistence of renal vestige in the absence of ureter have been described. However, but only one will be reported in connection with arrest of renal system. In this case the ureter may have been resorbed entirely and the kidney only partially.

It has been observed that the relationship of the posterior cardinal and subcardinal vessels to the wolffian ducts and metanephric blastema is such that the vessels might impede the growth of the latter organs in some cases (3).

In the cases to be reported it must be assumed that where a vestigial ureter was present sufficient contact with the renal blastema failed to occur to prevent complete resorption of the formed kidney anlage. In 1 case, No. 27 the presence of a vein where that of the kidney should have been indicates that some vestige of kidney tissue reached the renal fossa before it was resorbed or that ureteral growth is sufficient to stimulate growth of the renal vessels. In most cases in which such vessels are found a careful search will reveal the presence of remnants of a renal anlage.

The complete absence of the ureter in most cases of renal agenesis indicates that the usual cause of agenesis is faulty development of the urinary organs which precede the ureteral bud. The presence in some cases of a dimple at the site of the missing ureter or of a ureter extending only through the bladder wall suggests that only a bud ever developed or that resorption of the remainder of the ureter occurred in these cases. The absence of the suprarenal gland on the same side as the kidney is not a necessary concomitant for the diagnosis of renal agenesis as has been suggested. It is only a coincidence or occurs in those cases in which the absence of both results from some primordial disturbance.

BILATERAL RENAL AGENESIS

Amolsch in 1937 collected 115 instances of bilateral anephrogenesis from the literature and reported 4 additional cases. Soloway in 1939 reported 2 more cases. Grim, in 1940 reported a case without other congenital abnormalities. This brings the total number of such cases exclusive of those reported here to 122. Three more cases, from approximately 27,000 autopsies performed at the Los Angeles County Hospital are reported here. In addition there are 2 cases of unilateral agenesis with extreme aplasia of the opposite kidney (Cases 16 and 18).

In the series collected by Amolsch the ratio of males to females was 27 to 1. No explana-

tion for this sex differentiation has been offered. A lesser preponderance of males over females was found by Collins in the reported cases of unilateral renal agenesis. This is in contrast to the finding that ureteral anomalies of duplication are 27 per cent relatively more common in women than in men (15). The explanation may lie in the increased development of the wolffian duct in males in whom it forms a functioning portion of the genital system as well as of the urinary tract. This may increase the chance of maldevelopment of the kidney as most cases of renal agenesis result from failure of the ureter to develop properly and its development is dependent upon that of the wolffian duct.

Amolsch found multiple organ and system dysplasias in most cases of bilateral renal agenesis. He found but 3 male cases with developmental deficiencies limited to the metanephric and mesonephric structures. In 2 female cases the associated maldevelopments were limited to the müllerian duct derivatives.

CASE REPORTS

CASE 1: Baby D was a stillborn premature Caucasian male infant measuring 43 centimeters in length and weighing 1840 grams. There were no external anomalies. The foramen ovale and ductus arteriosus were patent. Both kidneys and ureters were absent. No remnants could be found. The adrenal glands were present and normal. The bladder measured only 3 millimeters in diameter. The prostate was small. Both testes lay along the rim of the lesser pelvis. The epididymides and vasa deferentia were not dissected in detail.

CASE 2: Baby IV, a Caucasian male infant, lived 45 minutes. There were no external abnormalities. No gross or microscopic evidence of renal tissue or of ureters or bladder were found. The urethra began behind the symphysis pubis and was patent. The adrenal glands were present and normal. The testes were in the abdomen. No further dissection was made. The postmortem creatinine was 3.5 milligrams per cent.

CASE 3: Baby H, a Caucasian male infant, lived 1 hour and 21 minutes. Both kidneys and ureters were completely absent. The urachus ended in a 1 by 1 by 1 centimeter fleshy mass which was comprised of the prostate and undeveloped bladder. The urethra was patent. The testes were in the scrotum. The vasa deferentia were not dissected. The adrenal glands were present and normal.

All of the 3 cases of bilateral anephrogenesis reported here were males. Contrary to the

general rule, these 3 infants had few other congenital defects. The suprarenal glands were present in each. It is unfortunate that the seminal vesicles and vasa deferentia were not described in any and it is probable that a minute search for them was not made. The absence of any ureteral remnants suggests that the wolffian ducts failed to develop and if this were true it would result in agenesis of the ejaculatory ducts, seminal vesicles and vasa deferentia. The body and tail of the epididymis as well as the ureter and kidney are also usually absent in such cases.

Vesical aplasia is the rule in these cases of bilateral renal agenesis as in all instances in which urine is never formed (Cases 16 and 18 also). Boyden has shown that the mechanical distention of the allantois of chicks by mesonephric secretion is essential for development of that organ. It is logical to assume that the same mechanism plays a part in the development of the human urinary bladder.

UNILATERAL RENAL AGENESIA

Unilateral renal agenesis is approximately five times as common as the bilateral form. The incidence of unilateral renal agenesis in the autopsy series reported in the literature is extremely variable as it is in the two series of autopsies included in this study. The reasons for this are not apparent. Eisendrath, for earlier reports. Campbell in 1928 reported 9 cases found in 13,000 autopsies at Bellevue Hospital, 1 to 1,444 cases. The incidence of those in the literature including his own he found to be 1 in 1,670 cases. Collins collected 572 cases from the literature and reported 9 cases found in 6,349 postmortem examinations an incidence of 1 to 705 autopsies at the Mayo Clinic. There were 367 instances of renal agenesis in 337,488 cases in the literature in which necropsy was performed or 1 in 920 postmortem examinations. Soloway found the ratio at Cook County Hospital to be 1 case to 1,200 autopsies.

Collins' statistics are the most comprehensive ones available. Of the 512 cases in which sex was indicated 55 per cent were males and 45 per cent females. The left kidney was absent in 57 per cent of the 556 cases in which

the side was mentioned and the right in 43 per cent. Approximately two-thirds of the patients were over 21 years of age. The solitary kidney was enlarged in 84 per cent of the 366 cases in which the size was mentioned. The average weight in 87 cases was 279.63 grams. The ureter was recorded as absent on the side of the renal agenesis in 297 cases (81 per cent). The ureter was present but obliterated in 11 cases and obliterated only in the cephalic portion in 23 cases. The ureter was mentioned as being completely patent in 8 cases. In the 460 cases in which the condition of the kidney was stated 61 per cent were normal and 39 per cent diseased. Death occurred from diseases unrelated to the genitourinary tract in 69 per cent of the cases. The adrenal gland was recorded as being absent on the side of the renal agenesis in only 68 cases. The gland was normal in 129 cases.

MATERIAL STUDIED

Fourteen instances of unilateral renal agenesis were found in approximately 27,000 autopsies at The Los Angeles County Hospital an incidence of 1 to 1,919 autopsies (Cases 4 through 17). Five cases of unilateral renal agenesis were found in 1,831 necropsies performed by Dr. Alvin G. Foord at The Huntington Memorial Hospital Pasadena, an incidence of 1 in 366 cases (Cases 18 through 22).

In addition 8 cases observed clinically at The Los Angeles County Hospital and in private practice are reported (Cases 23 through 30).

CLINICAL CASE REPORTS

CASE 23. A 30 year old male complained of epigastric pain 1 1/2 hours after meals. There was a history of transurethral fulguration of a vesical polyp 6 months before entry. Blood pressure was 130/74. Phenolsulfonphthalein appeared in 6 minutes. During the first half hour 55 per cent of the dye was excreted and during the second half hour 2 per cent. The urine contained 30 leucocytes to the high power field and gram-positive cocci and gram-negative bacilli. Retrograde pyelography showed a ureter on the left which was small and blind above. An excretory urogram contributed no additional information. The right kidney was large. At operation the left loin was explored and the ureter was found to extend almost to the diaphragm and to terminate in fibrous bands. No vestige of

renal tissue was found and the left adrenal gland was not identified. The patient was subsequently operated upon for a duodenal ulcer.

CASE 24. A 20 year old female complained of urinary frequency and burning since the age of 3 years. Blood pressure 120/84. The urine contained 20 to 30 leucocytes to the high power field and gram-positive cocci and gram-negative bacilli. The phenolsulfonphthalein appeared in 4 1/2 minutes. There was 35 per cent in the first half hour specimen and 5 per cent in the second half-hour specimen. Plain roentgenograms and excretory urograms showed a normal kidney on the right and none on the left. A catheter could be introduced only 3 centimeters up the left ureter. At operation the left loin was explored and no kidney or ureter found. The left adrenal gland was present and apparently normal.

CASE 25. A 48 year old man had noticed an enlarging mass in the right side of his abdomen for 3 years. He had had right flank pain, apparently of renal origin, for many years. He was known to have progressive muscular dystrophy. The blood pressure was 150/80. The urine was negative. The phenolsulfonphthalein appeared in 5 minutes. The first half hour specimen contained 40 per cent and the second 5 per cent of the dye. Kidney study revealed that the right kidney was large and ptosed, so that when the patient was standing over half of it was below the pelvic brim. There was slight caliectasis. No left renal shadow could be seen and no left kidney was visualized by excretory urography. The left ureteral orifice could not be identified and the left half of the trigone was absent. The left testis was not in the scrotum. No operation was performed.

CASE 26. A 3 year old female complained of urinary frequency and dysuria and intermittent hematuria for 3 years prior to entry. Blood pressure 115/70. The urine was negative. Cystoscopic examination revealed an absence of the right half of the trigone and of the right ureteral orifice. A pelvic mass was present. There was no vaginal orifice. Exploratory laparotomy revealed a small vestigial mass believed to represent the uterus and vagina attached to the left fallopian tube. The right tube was separate from it. There was a cake-shaped retroperitoneal mass in the midpelvis which was an ectopic kidney. The right kidney area was examined and a renal tissue found. Excretory urograms made later showed no kidney shadows in the lumbar areas and no dye excretion, except by the ectopic left kidney.

CASE 27. A 16 year old female had been known to have hypertension as high as 180 millimeters of mercury for 3 years. The urine was negative. There was moderate hypertrichosis. No genital abnormalities were found. Excretory urography showed a large left kidney but no kidney on the right. A retrolateral catheter could be introduced up the right ureter to about the level of the third lumbar vertebra where the ureter ended blindly as demonstrated by ureterogram. The right loin was explored, but no vestige of renal tissue was found. There was a vein

about 3 millimeters in diameter which arose from the vena cava in the normal position of the right renal vein. It passed directly into the psoas muscle. The right adrenal gland was present and appeared to be normal.

CASE 28. A 43 year old male complained of left flank pain of 3 days duration. A stone had been removed from his left kidney when he was 14 years old. Blood pressure was 130/80. He was passing 100 cc. of urine. Nonprotein nitrogen was 120 milligrams per cent. Roentgenograms showed a large left kidney and a calculus in the left ureter. No right kidney shadow was seen and no intravenous dye was excreted on the right. The right side of the trigone and the right ureteral orifice were absent. No operation was performed.

CASE 29. A 36 year old female had an enlarging pelvic tumor which she had known to be present for 11 years. Her blood pressure was 170/110. Urine was negative. Excretory urograms showed an enlarged left kidney and no kidney shadow on the right. Cystoscopy showed the right half of the trigone and the right ureteral orifice to be absent. The bladder was distorted by a large cystic mass in the right side of the pelvis. Exploratory laparotomy disclosed no right kidney or ureter to be present. The uterus was didelphic. The right half was distended with old blood. The right tube and ovary were not found.

CASE 30. A 36 year old female complained of severe right flank pain and urinary frequency and dysuria of several hours duration. Blood pressure was 128/70. There was pyuria. Excretory urograms showed a right kidney about twice average size and otherwise normal. There was no kidney shadow nor evidence of excreted dye on the left side. The left half of the trigone and the left ureteral orifice were absent.

ANALYSIS AND DISCUSSION OF UNILATERAL AGENESIA

Twenty-seven cases of unilateral renal agenesis are reported. Nineteen of these were autopsy cases and 8 clinical. Of the 8 clinical cases 5 were proved by exploration and there seemed to be no doubt about the other 3. In the statistical analysis the autopsy and clinical cases are considered together.

Sex. There were 18 (67 per cent) males and 9 (33 per cent) females. It is of interest that in the clinical cases the females outnumbered the males 5 to 3 while in the autopsy cases the males outnumbered the females 15 to 4. This may be due to the greater incidence of urologic disease in women with this anomaly than in men as seems to be the case with ureteral anomalies (15). In The Los Angeles County Hospital autopsies unilateral renal agenesis

was approximately 20 per cent more common in men than in women when corrected for the percentage of autopsies performed upon males and females. The preponderance is less than most of the literature indicates.

Race. All of the patients reported here were Caucasian.

Age. Comparison of the age distribution of the autopsy cases with that of all of the autopsies shows no significant deviation except for a considerably higher death rate under one year of age. All of these deaths were due to maldevelopment of the solitary kidney.

The youth of the patients of the clinical series indicates a tendency for urinary tract pathology or of the concomitant congenital abnormalities to make themselves known early in life.

Urinary tract. The right kidney was absent in 14 cases (52 per cent) and the left in 13 (48 per cent).

The ureter and the corresponding half of the trigone were totally absent on the side of the renal agenesis in 21 cases (77 per cent). In 3 cases the ureter extended only through the wall of the bladder. In 1 case the ureter was patent for 2 inches and extended farther as a fibrous thread. In 2 cases the ureter was patent as high as the lumbar region.

In 17 cases the suprarenal glands were present on both sides. In 1 case the suprarenal gland on the side of the renal agenesis was vestigial. In 9 cases the suprarenal was not looked for or not mentioned. It was recorded as absent in no case.

The solitary kidney was enlarged in all but 4 cases. Of the latter 2 contained no functioning renal tissue (Cases 16 and 18) and 1 contained very little (Case 22). 1 was a contracted kidney of chronic glomerulonephritis (Case 7). The usual enlargement was one and one half to two times normal size.

In 11 cases (41 per cent) there were congenital abnormalities of the solitary kidney or ureter. There were 3 instances of partial duplication of the ureter. In 1 case the single ureter opened in the midline of the bladder. In 1 case there was an unusually high ureteral take-off from the renal pelvis. In 1 case there was a congenital stricture of the lower end of the ureter with consequent dilation and renal

hypoplasia and atrophy. In 2 cases the kidney was a small mass of cysts only. In 2 cases there were solitary cysts. In 1 case there was an aberrant renal artery which passed in front of the vena cava. If only the autopsy cases are considered 58 per cent had some congenital abnormality of the solitary kidney or ureter.

In 3 (19 per cent) of the autopsy cases besides the 3 with aplastic solitary kidneys the cause of death was renal failure, 2 renal tuberculosi and 1 chronic glomerulonephritis. In another case acute glomerulonephritis of the single kidney was a contributory cause of death. Two of the patients seen clinically had disease of the solitary kidney: 1 calculous pyonephrosis and 1 acute pyelonephritis.

In 6 cases (22 per cent) there were developmental defects of the genital organs. Four of these were women and 2 men. Thus 44 per cent of the women and 11 per cent of the men had such abnormalities. In the women these were as follows: 1 absent tube and ovary; 1 tube which did not connect with the uterus; 1 in which the uterus and vagina were vestigial; 1 in which the tube and ovary were absent and the uterus was didelphic. The genital defects in men were as follows: in 1 the vas deferens and testis were absent; in the other one testis was absent; the other was atrophic; there was hypospadias and scrotal atrophy.

Genital defects are not noted as easily or looked for as assiduously in males as in females; hence may have been missed in some cases. Genital abnormalities do occur more commonly in women than in men. This is evidently because the müllerian duct is a later development than the wolffian duct.

Only 3 (21 per cent) of the 14 patients on whom accurate blood pressure readings were obtained had a systolic pressure above 140 or a diastolic pressure above 80.

From the study of a large group of all kinds of anomalies of the upper urinary tract it is apparent that there is little hope of distinguishing renal agenesis from renal aplasia clinically with any degree of certainty. Abnormality of one-half of the trigone is much more indicative of agenesis than of aplasia. Abnormality of one ureteral orifice or representation of the orifice by a mere dimple or termination

of the ureter just beyond the bladder wall occur more commonly with renal agenesis than with renal aplasia. However there are all degrees of ureteral aplasia with renal aplasia, as will be shown in a subsequent study of the latter subject. In some cases of renal aplasia and of renal degeneration due to disease agenesis is ruled out by the presence of a renal shadow or the concentration of a minute amount of urographic dye in the tissue present.

The size of the functioning kidney is no greater with renal agenesis than with renal aplasia.

The presence of developmental defects of the genital organs suggests the possibility of urinary tract dysplasias. Isolated renal agenesis is the most common of these.

SUMMARY

1. Renal agenesis implies the complete absence of renal tissue.

2. The renalanlage develops in most cases, even in the absence of a ureter, but is usually resorbed unless normal fusion with the ureter occurs.

3. Renal agenesis probably results in most cases from defective germ plasm. The mechanism of development is variable.

4. Three cases of bilateral renal agenesis from a series of 27,000 autopsies are reported. This makes the total number of such cases reported 124. Besides the 3 cases reported here only 3 other cases in which the abnormal kidneys have been limited to the mesonephric and metanephric systems have been reported.

5. Twenty-seven cases of unilateral renal agenesis are reported. Fourteen of these occurred in a series of 27,000 autopsies at The Los Angeles County Hospital; a ratio of 1 to 1,831. Five were found in a series of 1,831 autopsies at The Huntington Memorial Hospital; an incidence of 1 to 366 autopsies. The ratio for the combined series is 1 case to 1,517 autopsies. Six clinical cases are reported herein.

6. There were 18 (67 per cent) males and 9 (33 per cent) females. Unilateral renal agenesis was 20 per cent more common in males than in females of the autopsy series (corrected for the fact that 60 per cent of all of the autopsies were performed upon males).

7 The age at death of the patients with unilateral renal agenesis did not differ appreciably from that of the autopsy cases in general.

8 The clinical cases were all under 49 years of age.

9 The right and left kidneys were absent with equal frequency.

10 The suprarenal gland was definitely present in 17 cases and recorded as absent in none.

11 In 21 cases (77 per cent) the ureter and one half the trigone were entirely absent.

12 The solitary kidney was always enlarged unless shrunk by disease.

13 Fifty-eight per cent of the autopsy cases had congenital abnormalities of the single kidney.

14 Twenty-two per cent of the patients had disease of the single kidney. In 6 cases renal failure was the cause of death, 3 due to congenital inadequacy of the single kidney and 3 due to renal disease.

15 Four (44 per cent) of the women had developmental defects of the genital organs.

Two (11 per cent) of the men had such defects.

16 Only 3 (21 per cent) of the autopsy cases had hypertension.

17 There is no reliable clinical sign which guarantees the diagnosis of renal agenesis in distinction from renal aplasia.

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THE MANAGEMENT OF UTERINE MYOMAS

A Study Based on 1000 Consecutive Personal Cases and Illustrating the Technique of Panhysterectomy

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UTERINE myomas, tumors made up of smooth muscle and connective tissue in varying proportions and enveloped by a definite capsule of condensed muscle tissue from which they derive part of their blood supply are among the most frequent lesions in gynecology and their management comprises one of its most important chapters. The treatment of these neoplasms depends upon their size, their location in the uterus, their symptomatology and the age of their host. It will be discussed under three broad divisions—observation, surgery and irradiation with radium or high voltage x ray.

OBSERVATION

The smaller tumors which are not productive of symptoms the chief of these being hemorrhage and pressure require no treatment. Women with such new-growths are advantageously kept under observation, being examined every year or even every 6 months, since in the course of time symptoms may develop. Pain and hemorrhage may be slight or may be very severe. For those whose symptoms require treatment, two methods are available—surgery and irradiation.

Before the advent of radium and high voltage x rays, which are still relatively recent procedures, surgery in one form or another was the only means of combating this disorder.

SURGERY

Myomectomy abdominal and vaginal. Myomectomy which may be performed through the vagina or through the abdomen consists of the enucleation of the myomas and the recon-

struction of the uterus so that its two main functions, menstruation and reproduction, may be conserved. While more difficult of execution than ablation of the uterus, this intervention offers a reward in the fact that it prevents castration and also permits many women in the childbearing age to which it is almost entirely applicable to gratify their desire for the physiological function of maternity. Even in some who are approaching the menopause the prevention of castration has a salutary influence on their physiological life.

The manner of handling this problem in women still in the childbearing age and anxious to have progeny depends on whether or not they are sterile. In those who can conceive the best method is to allow the pregnancy to take place and deliver them at term by appropriate means. For those whose tumors are responsible for sterility myomectomy offers the greatest advantages. All gynecologists who perform myomectomy under these conditions have had a number of patients who have gone through uncomplicated pregnancies and been delivered of normal children. If pregnancy does occur after this operation, two methods of delivery are effectual, according to the circumstances. If the tumors were subserous or intramural if the uterine musculature was not markedly weakened and if the uterine cavity was not opened to any great extent, it is advisable to allow these patients to go through labor and to deliver them by forceps when the vertex becomes easily accessible in order to prevent undue strain on the uterus during the period of expulsion. If the tumors were submucous and as frequently happens, the uterine cavity was invaded to a considerable degree, it is safer to deliver them by cesarean section before the onset of labor in order to minimize the possibility of uterine rupture. Furthermore gravidæ who were

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originally sterile and who become pregnant after myomectomy seldom have large families and it is disastrous to lose the infant and sacrifice the uterus because of rupture in an attempt to bring the product of conception into the world. Again a number of these women are fairly well advanced in years, obstetrically speaking because of this fact their cervixes may be rigid and thus a long and ineffectual first stage of labor results. Although it is true that by following this regimen a few unnecessary cesarean sections may be performed on the whole this procedure surrounds the delivery with greater protection than does forceps carried out in women whose tumors are easily overlarge and in whom, because of previous childbirth there is some dilatation of the vaginal tube. In nulliparous women and in those whose tumors have reached considerable size, the operation can be better performed through an abdominal incision.

Hysterectomy abdominal and vaginal. In the younger group of patients in whom myomectomy is not feasible in those who are the hosts of large tumors and in those who have reached or passed the menopause hysterectomy has to be considered. A choice must be made from three types of operation—fundic hysterectomy and panhysterectomy. These will now be discussed. In *fundic hysterectomy* the fundus of the uterus is amputated but enough endometrium is retained to allow menstruation to continue decreased in amount though it may be and the patient is thus relieved of the odium of castration. This fact is especially valuable in the premenopausal age group in women contemplating marriage and in those who have been recently married. *Supracervical or supravaginal hysterectomy* which consists of the amputation of the uterus at the isthmus possesses only one advantage over the total ablation of the uterus namely that sexual congress can be carried out more satisfactorily if a normal or well healed cervix, well suspended in the vaginal vault is retained. This advantage however is not sufficient to justify the retention of a diseased cervix, with lacerations ectropion chronic endocervicitis and cystic degeneration benign though those

lesions may be. For this reason I now perform supravaginal hysterectomy only under rare conditions. There is another serious factor which governs the choice between supracervical hysterectomy and panhysterectomy—the question of operative mortality and morbidity. In the hands of a well trained pelvic surgeon who performs a hundred or more hysterectomies yearly there is no great difference between the two methods in mortality and morbidity but such is not the case in the hands of an operator who performs but few of these operations probably 6 to 12 yearly. Statistics show that under such circumstances the mortality of panhysterectomy over that of supracervical hysterectomy may be seriously increased in some series as much as 10 per cent. From the standpoint of morbidity the injuries to the bladder and ureters are most apt to occur with surgeons who perform the operation infrequently since numerous statistics in the literature of the last decade have shown that these accidents very seldom occur when panhysterectomy is performed by surgeons of wide experience. If for one reason or another it is decided to perform supracervical hysterectomy two steps become essential—a second appropriate treatment of the cervix and that is to be retained. The main reason for the selection of panhysterectomy is to prevent the subsequent development of carcinoma of the cervical stump and since it seldom does develop on a healthy cervix, it is of prime importance to heal the cervix that is to be retained. After trying trachelorrhaphy conical amputation and total amputation of the cervix, I have like many other gynecologists come to the conclusion that thorough cauterization of the cervix is the best and simplest method at our command. In a number of cases cervical carcinoma has been found to exist at the time supravaginal hysterectomy for fibroids was performed. Most authors agree that a stump carcinoma which appears within a year after operation was present at the time of the intervention. Among a number of cases of stump carcinoma 2 that were consecutive to supravaginal amputation of the uterus for fibroids came to my attention. These were both referred by the same surgeon

and had occurred within a few months of each other. The diagnosis in each instance was made by the pathologist by obtaining cancer cells from the cut surface of the uterus which had been submitted to him. In both cases the myomas had been felt through the abdomen and no vaginal examination had been made previous to operation. When supracervical hysterectomy is considered it is my custom, at the time of the original examination to inspect the cervix, with a proper speculum and under a good light to take a biopsy of any suspicious lesions, and to obtain a histological report within a few days since it is impossible for the naked eye to distinguish between chronic cervicitis and early carcinoma. In so far as thorough cauterization of the cervix before supracervical hysterectomy for uterine myomas is concerned there are two schools of thought as to the time that this should be performed. There are those who believe that the cervix should be cauterized some weeks before the major intervention in order that it may be well healed since if this procedure is carried out as a preliminary step to the operation infectious phenomena will develop. On the other hand there are those who believe that the cauterization should be done just before operation. I subscribe to the latter opinion and in a rather large series of patients so treated no serious infections have been observed. Supravaginal hysterectomy must be considered when a large amount of vaginal plastic work has been done, when the cardinal ligaments or ligaments of Mackenrodt have been utilized in the process, and when the uterus has to be sacrificed for large tumors.

Panhysterectomy or the ablation of the entire uterus, is constantly gaining ground. It is advocated by a large number of well trained specialists, and, as previously stated, its mortality and morbidity when the operation is done by such specialists, are no greater than those of supracervical amputation. Obviously it is the surest prophylaxis against stump carcinoma when it is performed for benign lesions it suppresses an annoying leucorrhoea which may persist when the cervix is retained and it is the only type of hysterectomy that should be considered if malignant degeneration exists in the uterine corpus. In my own

practice panhysterectomy is resorted to in the average case while supra-cervical hysterectomy is reserved for special cases.

The question of closing the vagina tightly or draining it after panhysterectomy frequently arises. As a general rule, tight closure of the vagina is used routinely in my cases, especially since the advent of the sulfa drugs. After peritonization 5 grams of sulfanilamide is left in the cul-de-sac of Douglas. Drainage is reserved for those cases in which there is considerable oozing from raw surfaces, such as exist when one is operating in the presence of extensive endometrioids, or for pelvic inflammatory disease, in which cases the sigmoid is sutured across the pelvis to the edges of the peritoneum of the broad ligaments and the bladder to roof it over. Under these circumstances, a vaginal drain to allow the escape of serum or serosanguineous fluid from the pelvis is advantageous.

Fundic, supracervical and panhysterectomy may be performed through the abdomen or through the vagina. In America the abdominal route has always had the preference. However in old people and in those who are poor surgical risks, the vaginal approach has certain merits. As previously mentioned it is simpler of execution in those who have some relaxation of the vaginal tube following child birth. It may be performed by means of sutures, the commonly used method, or by means of clamps which are left *in situ* as suggested by James W. Kennedy of Philadelphia. Each procedure has its place. In the type of patient mentioned, the removal of large tumors by morcellation followed by the ablation of the shell of the uterus by sutures or clamps, offers a mode of operation which carries but little shock and is therefore beneficial. This method evidently necessitates an extensive experience in vaginal operating, but the operative trauma is directed against the buttocks rather than the peritoneal cavity.

IRRADIATION RADIUM AND X RAY

Still another method of treating uterine myomas is by means of radium and high voltage x-ray. The superiority of radium rests on the fact that but one treatment is usually necessary and that the radioactive substance

is applied directly in the uterine canal so that the necessity of the rays traversing the abdominal wall in order to reach the uterus and ovaries is obviated. The commonly accepted dose of radium for uterine myomas varies between 1500 and 2400 milligram hours. X rays delivered to the pelvis by a suitable apparatus also play their rôle. It should be an inviolate rule that a diagnostic curettage to rule out a malignant neoplasm of the endometrium must precede either method of irradiation. Certain classes of tumors constitute definite contraindications to this form of therapy in the management of uterine myomas and these were well elucidated by Clark and Keene both of the University of Pennsylvania School of Medicine in the early days of its application. They are as follows: tumors larger than a 3 months gestation rapidly growing tumor suggesting progressive changes; tumors producing pressure symptoms; tumors associated with pelvic pain; pedunculated tumors in which irradiation tends to increase necrosis; tumors associated with adnexal pathology; tumors associated with cachexia; tumors in young women; multiple submucous tumors; association with pyometra; and tumors in women who fear radium.

The surgical management of uterine myomas has yielded some of the most brilliant results of pelvic surgery. Improved preoperative and postoperative care, the liberal use of blood transfusions to replace lost blood, the transfusion of blood plasma always available during the operation to prevent or overcome shock, resort to the sulfa drugs to prevent or combat infection, and vein ligation for thrombophlebitis have all played their part in reducing mortality and morbidity and have made surgery a safe procedure in the management of these neoplasms. Again surgical intervention permits one to inspect the ovaries and to remove those which show pathologic changes thereby reducing or obviating the development of ovarian carcinoma some years later, a condition which I have observed in more than one case. Besides if hysterectomy is performed as is done in the majority of cases, the danger of later development of carcinoma of the uterus, cervical or corporal, is avoided. I have seen this development in the

cervix or corpus of the uterus 10 and even 15 years after irradiation for benign lesions. Because of the foregoing my preference in the management of symptom producing myomas is surgical interference, irradiation being reserved for the cases in which surgery is contra-indicated because of impaired physical condition and disease of the vital organs such as the heart, kidneys, liver and lungs, and because of severe hypertension.

TECHNIQUE OF ABDOMINAL PANHYSTERECTOMY

Space does not permit giving in detail the techniques for all the mentioned methods of treating uterine myomas. Abdominal panhysterectomy being the most extensive operation performed for these tumors, it may be of some value to describe and illustrate it. As I perform it, the patient is anesthetized, the vulva and the vagina are prepared with tincture of zephiran and a plain gauze wick, the end of which has been saturated with tincture of zephiran, is placed against the cervix and vaginal vault and left *in situ* until the vagina is opened from above. A sponge forceps is attached to the loose end of the gauze which is left between the thighs in order to facilitate its removal during the operation, and the urinary bladder is catheterized. The abdomen is prepared with 95 per cent alcohol with an aqueous solution of zephiran and tincture of zephiran, the sterile drapings are applied and after the patient has been placed in the Trendelenburg position the abdomen is opened by a median incision extending from the symphysis pubis to the umbilicus. Rarely is it necessary to extend the incision above the umbilicus. After the skin edges are covered with sterile towels the abdominal organs are explored and the intestinal mass is reduced above the pelvis and held in place by gauze pads so that the pelvic organs are exposed. The operation is continued as follows:

Step 1. The uterus is raised out of the pelvis being held by an assistant if the tumors are large by applying Ochsner clamps on the broad ligaments close to the uterus or by picking up the uterus with a suitable vulsellum forceps. If the adnexa are retained, the upper part of the broad ligament including the tube

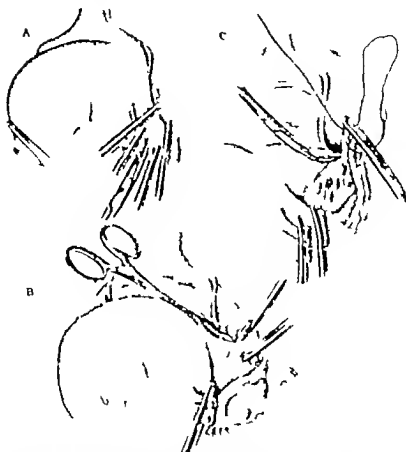


Fig. 1. A, Adnexa conserved. The upper part of the right broad ligament, including the tube and the ovarian ligament, is cut between clamps, close to the uterus. The right round ligament is similarly cut. B, The upper part of the right broad ligament and the right round ligament have been clamped and cut, and their pedicles are shown. C, The clamps are immediately replaced by suture ligatures of No. 1 chromic catgut, the vessels being doubly ligated. The pelvis is thus cleared of all unnecessary clamps and the subsequent steps of the operation facilitated. The ligaments on the left side are treated in a like manner.

and ovarian ligament on one side is cut between clamps. The round ligament of that side is similarly treated. The clamps on the pedicles are immediately replaced by suture ligatures of No. 1 chromic catgut in order to keep the pelvis free of clamps and obtain a clearer field. All the vessels are doubly ligated. This process is repeated on the opposite side. If the adnexa are to be sacrificed the clamps are placed on the Infundibulopelvic and round ligaments. The ligatures can be applied more securely if the pedicles have been clamped and cut than they can if the vessels are tied *in situ*

(Fig. 1, A, B, C.) Figure 2, A shows the ligation of the infundibulopelvic ligament and the round ligament on the right side.

Step 2. The uterovesical peritoneal fold is incised to the round ligament on each side and the bladder is freely separated from the cervix and the upper part of the vagina. The uterine vessels are clamped and cut below the uterine isthmus by means of the three clamp method. The uterine vessels are doubly ligated with No. 1 chromic catgut after the clamps have been removed one by one. A special clamp having a short jaw at an obtuse angle

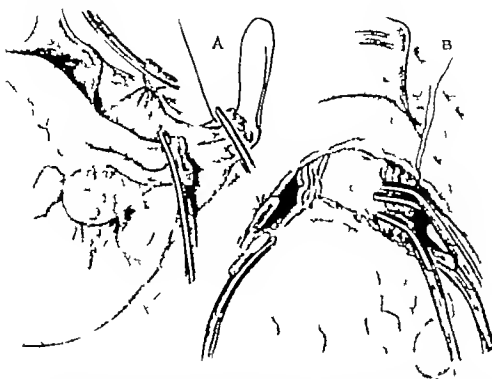


Fig. 2 A, Adnexa sacrificed. The right infundibulopelvic ligament and the right round ligament have been cut between clamps, which are replaced by suture ligatures of No. 1 chromic catgut, the vessels being doubly ligated. This procedure is next carried out on the left side. B The vesical peritoneum is incised to the round ligament on each side, and the bladder is separated downward from the cervix and the upper part of the vagina. The uterine vessels are cut between clamps, by the 3 clamp method, and are doubly ligated on each side.

and an Ochsner point, which I have had constructed facilitates the ligating of the uterine vessels. This process is then carried out on the opposite side. If the clamps on the uterine vessels have been placed low enough the vaginal vessels are included in them and tied at the same time (Fig. 2 B).

Step 3 The cardinal ligaments or ligaments of Mackenrodt on each side of the cervix are cut so that the uterus is allowed to be raised considerably in the pelvis through the abdominal incision. If the vaginal vessels were not included in the uterine pedicle clamps they are picked up separately and ligated with No. 1 chromic catgut. The bladder is inspected to ascertain that it has been sufficiently mobilized downward; this mobility is important as it prevents injury to this viscus in the subsequent steps. The vagina is opened posteriorly and to the left since there are no important structures in this area and the incision is carried circularly around the cervix, care being taken to remove as little of the vagina as pos-

sible in order not to shorten it. The vaginal edges are then picked up by suitable clamps and the entire uterus is removed. I have had special vaginal clamps constructed for this purpose. These have a short jaw with an Ochsner point and a long handle. They do not tear the edges of the vaginal incision and the long handle facilitates the suturing of the vagina (Fig. 3 A and B). If there is much oozing from the cut edges of the vagina a gauze sponge the end of which has been impregnated with tincture of zephiran is pushed into the vagina to be removed at the end of the operation. If the vaginal edges are dry this gauze may be omitted (Fig. 3 B).

Step 4 The vagina is closed with either interrupted sutures or a continuous suture of No. 1 chromic catgut. If drainage is deemed advisable a small central opening is left through which a length of Penrose tubing is introduced to be removed in 72 to 96 hours. Under ordinary conditions the vagina is closed tightly. The cardinal ligament of each side is



FIG. 3. A. The bladder has been pushed down and the round ligament is cut. B. The vaginal vessels have not been included in the tissue removed. C. The vagina is opened posteriorly. D. The uterus is removed. E. The vagina is closed. F. The vagina is closed. G. The vagina is closed. H. The vagina is closed. I. The vagina is closed. J. The vagina is closed. K. The vagina is closed. L. The vagina is closed. M. The vagina is closed. N. The vagina is closed. O. The vagina is closed. P. The vagina is closed. Q. The vagina is closed. R. The vagina is closed. S. The vagina is closed. T. The vagina is closed. U. The vagina is closed. V. The vagina is closed. W. The vagina is closed. X. The vagina is closed. Y. The vagina is closed. Z. The vagina is closed.

end of the operation. If the vaginal edges are dry, they may be coated. C. The vagina has been closed. D. The vagina is closed. E. The vagina is closed. F. The vagina is closed. G. The vagina is closed. H. The vagina is closed. I. The vagina is closed. J. The vagina is closed. K. The vagina is closed. L. The vagina is closed. M. The vagina is closed. N. The vagina is closed. O. The vagina is closed. P. The vagina is closed. Q. The vagina is closed. R. The vagina is closed. S. The vagina is closed. T. The vagina is closed. U. The vagina is closed. V. The vagina is closed. W. The vagina is closed. X. The vagina is closed. Y. The vagina is closed. Z. The vagina is closed.

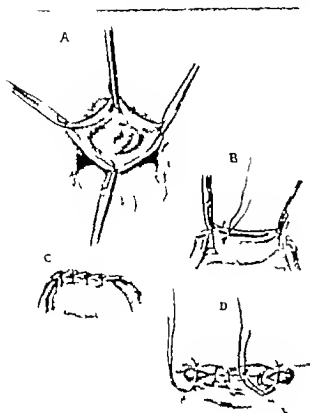


Fig. 4. A, B, C, Details of the closure of the vagina and the attachment of the cardinal ligaments and round ligaments to the vaginal edges. D Peritonealization when the adnexa have been removed.

attached to the side of the closed vagina to add to the support of the vaginal tube and the round ligament of each side is sutured to the vaginal cuff by a similar suture (Fig. 3 C).

The right uterosacral ligament and the edge of the bladder peritoneum on the right are picked up with a suture of No. 0 chromic catgut which runs as a continuous stitch until the left uterosacral ligament and the edge of the bladder peritoneum on the left are reached when it is tied. Thus the vaginal cuff and the pedicles of the uterine vessels are buried under peritoneum. The leaves of the broad ligaments on each side are next approximated by interrupted sutures or a continuous suture of No. 0 chromic catgut all raw areas being covered and the infundibulopelvic ligament pedicles buried if the adnexa have been sacrificed and the adnexal pedicles if they have been retained. At the completion of this step the pelvis is entirely peritonealized no raw edges being left. The hysterectomy is completed with adnexa retained (Fig. 3 D).

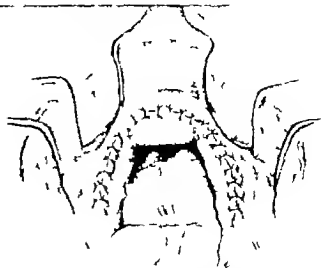


Fig. 5. The peritonealization of the pelvis when the broad ligaments have been widely opened in the removal of large or intraperitoneal tumors. The interrupted sutures prevent distortion of the broad ligaments and the kinking of the ureters. Five grams of sulfanilamide is placed in the cul-de-sac of Douglas before the sigmoid is brought down to the pelvis. By filling the pelvis with the sigmoid, small bowel adhesions to the suture line are prevented.

Figure 4 A B C and D shows the details of the vaginal closure the attachment of the cardinal and round ligaments to the vagina and the peritonealization when the adnexa have been sacrificed. When the broad ligaments have been opened widely as in the removal of intraligamentous myomas the peritoneal layers are approximated with interrupted sutures of No. 0 chromic catgut since kinking or displacement of the ureters is not so likely with this method as with a continuous stitch (Fig. 5).

Step 5 Five grams of sulfanilamide powder is placed in the cul-de-sac of Douglas and the sigmoid is brought down and placed in the pelvis in order to prevent the small intestine from coming in contact with the suture line thereby preventing adhesions and small bowel obstructions conditions which I have observed when this precaution was neglected.

Step 6 The omentum is spread over the intestines and the incision is closed in layers.

STATISTICS

The records of 1000 consecutive cases of myomas of the uterus which I have treated have been reviewed.

Regarding the method of treatment pursued 882 women received treatment for their

tumors in 118 who were treated for other conditions the diagnosis of uterine myoma was established. Two of the patients who had myomas also had carcinoma of the cervix and were managed by the Wertheim radical pelvic dissection. There were 994 white and 6 colored women in this series.

In the temporal analysis of the abdominal hysterectomies the cases were divided into three periods. The increase of panhysterectomy over subtotal was apparent as the time interval increased.

The handling of the adnexa in the treatment of the myomas is self-explanatory.

In the 118 untreated cases of myomas which were discovered or known to exist when the patients were treated for other disorders, 6 women had malignant disease—1 in the ovum, 1 in the breast, 2 in the cervix uteri, 1 in the kidney, and 1 in the rectum.

The youngest of the 1,000 patients was 20 and the oldest 76 years of age. The incidence was highest between the ages of 30 and 39 years and 40 and 49 years, which finding is in keeping with other statistics.

In the 48 cases in which myomas were complicated by pregnancy 4 patients had tubal pregnancies and were treated by hysterectomy and salpingectomy or salpingo-oophorectomy. There were 44 intrauterine pregnancies, with 18 vaginal deliveries, 14 low cervical transverse cesarean sections, and 12 cesarean hysterectomies (Porro) in 6 cases complications developed in 5 of which they were severe.

Table I lists additional pelvic disease found.

The additional pathologic lesions of all types found at operation were numerous and varied and they emphasize the advantage of surgery over irradiation in the management of uterine myomas since many such lesions may be treated at the time of operation.

Table II lists the supplemental operative procedures which were carried out.

TABLE I

Additional pathology found at operation

Adnexal infection	76
Ovarian cyst	50
Anal pathology	
Laceration of cervix	07
Cervical polyp	37
Intrauterine pregnancy	44
Chronic endocervicitis	7

Pelvic floor relaxation	9
Adhesions	110
Inguinal hernia	4
Parovarian cyst and cyst of Morgagni	20
Endometriosis and adenomyosis	1
Tubal pregnancy	4
Vulvovaginal abscess	3
Acute appendicitis	
Cholecystitis and/or cholelithiasis	43
Proctitis	14
Intestinal obstruction	4
Pelvic tuberculosis	
Diabetes mellitus	8
Malignancy elsewhere	6

Miscellaneous pathology found at operation

Umbilical hernia	
Ischiorectal infection	
Bilateral cystic kidneys	
Hemophilus	
Anemia of pregnancy	
Toxemia of pregnancy	
Placenta previa	
Thyroid disease	
Benign tumor of breast	
1 version of uterus	
Purulent vaginitis	
Perineal septicemia	
1 tracheal approach	

Additional pelvic pathology

Cervical myoma	39
Leiomyosarcoma	3
Decidual cyst	3
Ovarian fibroma	8
Adenocarcinoma of fundus	
Carcinoma of ovary	
Carcinoma of cervix	3
Adenoma malignum	
Papillary adenocarcinoma	3

The mortality was 2.8 per cent. It occurred in a large measure in the earlier cases. There were 4 deaths from shock or from shock and myocarditis. These were usually the result of loss of blood and poor physical condition before operation in the days when blood transfusion was not commonly practiced and plasma transfusion was unknown. Nowadays most of

TABLE II

Supplemental procedures at operation

Appendectomy	454
Trachelorrhaphy	4
Anterior colporrhaphy	
Posterior colporrhaphy	
Transplantation of ovaries	
Aspiration of cervix	28
Enterocoele repair	3
Plastic urethra	9
Perineorrhaphy	06
Interposition of uterus	
Interposition of broad ligaments	3
Obliteration suspension of the uterus	43
Kempson suspension of the uterus	4
Neck suspension of the uterus	

Ventral suspension of the uterus	7
Gilliam suspension of the uterus	9
Baldy Webster suspension of the uterus	3
Cholecystectomy	4
Vaginal drain	84
Abdominal drain	17
Shortening of uterosacral ligaments	10

Miscellaneous procedures at operation

Umbilical herniorrhaphy	4
Presacral neurectomy	4
Suprapubic cystostomy	1
Manchester operation	1
Kennedy operation	2
Trachelopexy	2
Schuchardt incision	2
Vaginal suspension	1
Kocher uterine fixation	1
Omental resection	3
Rectopexy	3
Vaginal hysterectomy	5
Bladder repair	3
Plannetschli incision	12
Battle incision	1
Nephrectomy	1
Ovarian suspension	18
Ileostomy	2
Colostomy	1
Kelly operation	3

these deaths could have been prevented by resorting to the liberal use of these agents. Septicemia or peritonitis or both accounted for 8 fatalities, which might or might not have been controlled by the sulfa drugs and transfusion. My records show that no one has succumbed to these complications for a number of years. This outcome has been prevented at least in part by bringing the patient to the operating table in improved physical condition replacing lost blood leaving sulfanilamide in the peritoneal cavity and administering sulfa drugs by mouth postoperatively when indicated. The 5 patients who died from cardiac disease would now be treated by means of radium without general anesthesia since the introduction of a radium tube in the uterus is not a very painful procedure especially if morphine and scopolamine are administered one half hour previously or if local infiltration anesthesia is employed. It is in these cases that irradiation shows the most brilliant results. Anuria accounted for 2 deaths in both cases the patency of the ureters was demonstrated after operation by cystoscopy and catheterization of the ureters. Irradiation with x ray following a diagnostic curettage under local anesthesia might have prevented these accidents since irradiation by

this means is more gradual and is given over a longer period of time than it is when radium is used. Pneumonia caused 3 deaths which again occurred at a time when the modern treatment of this disease was unknown and when these patients not being so well prepared for operation as they would be today were more liable to contract the disease. Inoperable carcinoma caused 2 deaths. This disease is beyond human control and the deaths must be accepted as inevitable. Transfusion reaction resulted in death in a patient whose blood had been cross matched with that of the donor the test was repeated after death and found to be correct. This transfusion was done at a time when not so much was known about blood incompatibilities as is the case today. Paralytic ileus resulted in the death of 1 patient in the earlier group of cases. This might have been prevented by the use of the Wagensteen apparatus had it been available.

From May 4 1937 to June 29 1943 when this study was completed a period of 6 years and 56 days 386 cases of uterine myomas were treated without mortality. A death which occurred on May 4 1937 took place on the operating table and was entirely due to the anesthesia although it had been conducted by a specialist in this field. This series without mortality by December 31 1943 reaches the figure of 407.

SUMMARY

1. Uterine myoma forms one of the commonest lesions in gynecology.
2. Its management by observation surgery and irradiation by radium or x ray is taken up in detail.
3. The technique of abdominal panhysterectomy the most extensive operation used in the treatment is elaborated and illustrated.
4. The importance of preoperative preparation of the liberal use of blood and blood plasma transfusions and of postoperative care is stressed.
5. One thousand consecutive personal cases of uterine myoma are reported.
6. The mortality in this series was 2.8 per cent. No deaths occurred in the last 386 cases.
7. Preference for surgery over irradiation when the former can be used safely is expressed.

BIOLOGICAL CHANGES IN SQUAMOUS EPITHELIUM TRANSPLANTED TO THE PELVIC CONNECTIVE TISSUE

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A CHINESE patient who was born with out a vagina was successfully operated upon by us to construct an artificial one. A space was opened between the bladder and the rectum. A split Thiersch skin graft was removed from the inner surface of the thigh applied to a pyrex glass mold of appropriate size so that the outer surface presented inward and inserted into the cavity. This thin layer of epithelium grew rapidly, acquired ridges or rugae, and a pink blue color. Within 6 months it had assumed to a remarkable degree the appearance of a normal vagina, a result which stimulated further studies. Another Chinese woman, L. Y. F. with the same anomaly but with poorly developed secondary sex characteristics, was operated upon on May 17 1947 and the details of the histories and technique of operation of these 2 cases are reported in an unpublished communication. In the second case we studied the histology chemistry and bacteriology of the transplanted epithelial membrane.

Histology The cellular structure of the skin and the vagina, except for minor details, is the same that is, stratified squamous epithelium. Although a split Thiersch graft was cut, it probably included some of the Malpighian layer and stratum germinativum, as identified by Maximow and Bloom. A biopsy specimen of skin was removed (Fig. 1) from the same area from which the Thiersch graft was taken. The specimen was stained for glycogen and showed normal skin with low papillae, very little glycogen, and a few sweat glands.

On July 9, or 53 days after operation, a biopsy specimen of the transplanted epithelium was taken from high up in the vault of the smooth and pliable cavity (Fig. 2). This section of the same magnification, and also stained for glycogen, showed that the epithelium had increased about six times in thickness, there were no sweat glands, the papillae were more prominent, and there was a considerable increase in glycogen content of the cells.

In 1927 Dierks (5, 6) described the histology of the normal human vagina and distinguished three principal layers: the basal layer functional layer

and zone of cornification. A narrow darker staining band of cells was described during the mid-interval in the intraepithelial zone of cornification. Dierks' layer or this band of darker staining cells, is to be noted in this section. The beginning accumulation of glycogen corresponds to the position of Dierks' layer. Davis and Hartman, using female monkeys, repeated Dierks' work and coordinated rhythmic changes in the epithelium with ovarian activity. Such changes may be associated with the present study to a minor degree.

On October 29, or 154 days after the operation, another biopsy specimen of the transplanted epithelium (Fig. 3) was taken from near the vault of the cavity. This photomicrograph is of the same magnification and staining and shows that the epithelium has increased in thickness to an average of ten times that of the skin biopsy, with no sweat glands or hair follicles. The papillae are deep and the epithelium is loaded with glycogen. The three principal layers which Dierks described for the normal vagina are to some extent, apparent in this transplanted epithelium.

Estrogenic substance was not given to this patient, in any form, until after all biopsies had been taken. On November 5 the patient was given stilbestrol, 2.5 milligrams, by intramuscular injection. This was repeated on November 8, and on November 11 progynon B oleosum (10,000 international units) was given, also by intramuscular injection. No increase in growth of the epithelium was noted but another biopsy was not taken. The patient presumably had some small amount of estrogen in her tissues, but it is clear that injections of this substance were not necessary for the graft to take and to grow luxuriously. A biopsy specimen (Fig. 4) was taken from the vagina of a normal patient of the same age group and was stained in the same way for comparison. Great similarity between the transplanted epithelium and the normal vaginal mucosa is apparent.

Chemistry Zwelfel, in 1877 was the first to notice that normal vaginal secretions are acid in reaction. Since then an enormous literature has arisen on this subject, and several methods have been devised for determining the chemical reaction of the vagina. One of us (Wang) used the quinhydrone microelectrode to determine the

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Fig. 1. Section of biopsy specimen from the skin of the inner surface of the thigh—full thickness. Best's carmine stain shows very little glycogen, low papillae, and sweat glands. $\times 120$.



Fig. 2. Section of biopsy specimen of transplanted epithelium 53 days after operation. Best's carmine stain shows increase in thickness, beginning accumulation of glycogen, and development of papillae. $\times 120$.

hydrogen ion concentration in vaginal washings of 3 cubic centimeters of sterile normal saline. It had been shown by Zuck and Duncan that the vaginal secretions are well buffered and can be moderately diluted without affecting the true value of the pH. Wang found the average on 27 Chinese patients with normal vaginal flora to be pH 4.52 and on 23 patients with mixed infection, the vaginal pH ranged from 5.04 to 6.67. The details of this work are to be published in another communication. These findings correspond to those of several authors in other countries and races (3, 10, 13). The pH of this artificial cavity as determined by the above method was as follows: July 9, 7.34; August 6, 7.65; October 8, 6.50; October 29, 6.74; and November 11, 6.50.

Bacteriology As early as 1897 Doederlein studied the vaginal bacterial flora and described a large gram positive bacillus now known as Doederlein's bacillus, which has been found only in acid media. Others have added much in formation and classified the flora. Smears were made from the transplanted epithelium at intervals, and on October 29 Doederlein bacilli and other mixed organisms were found (type II flora) which is in keeping with the degree of acidity.

COMMENT

The growth of this transplant is not a metaplasia, as the fundamental type of epithelium was retained; nor is it an overgrowth from the introitus, as the taking and growth of the graft was ob-



Fig. 3. Section of biopsy specimen of transplanted epithelium 154 days after operation. Best's carmine stain shows no sweat glands. The epithelium has increased ten times in thickness with marked papillae and is loaded with



glycogen as in the normal vagina. $\times 120$. See Figure 4.
Fig. 4. Section of biopsy specimen of the vagina taken from another patient and stained with Best's carmine for comparison. $\times 120$.

served through the glass mold. The conditions of growth, however, are at least similar to those of a culture of epithelium. The secondary sex characteristics of this patient were poorly developed and it does not appear that estrogen had much to do with the stimulation of the marked growth of the epithelium. One must look elsewhere for an explanation of the growth-stimulating factor. This patient left the hospital 1 month after operation, at which time the growth of epithelium was well advanced, and she returned frequently as an out-patient. What stimulating effect coitus may have had on the further development of this epithelium is difficult to evaluate. Carrel and Ebeling found that the growth of tissue cultures of fibroblasts *in vitro* depends entirely on substances contained in embryonic juice. Ebeling and Fischer working with epithelial cultures *in vitro* agree with Champy that epithelial cells in the presence of connective tissue cells do not dedifferentiate.

Drew showed in tissue culture that differentiation of epithelium of kidney or skin depends upon the presence of connective tissue elements. This is also mentioned by Huxley and De Beer. Drew also states that autolyzed extracts of normal adult tissues contain a growth-stimulating factor which when added to tissue cultures *in vitro* causes rapid proliferation of normal adult cells. It seems that the connective tissue elements must be injured in order to release the growth-stimulating factor. In our work the loose cellular tissue was extensively injured, which may account for the rapid initial proliferation of epithelium. It is probable that growth and differentiation of this epithelial transplant is, at least in part due to a substance elaborated by the surrounding pelvic connective tissue.

It is to be noted that the appearance of glycogen, the type II bacterial flora and the degree of

acidity appeared at about the same time, showing the interrelation of these factors.

SUMMARY

In absence of the vagina, a tubular membrane of epithelium was removed from the thigh and transplanted to the loose cellular tissue of the pelvis. The accumulation of glycogen in this growing epithelium in its new location was striking. The changing biologic characteristics of this epithelial tube were studied and it was found that within 6 months the cellular structure, acidity and bacterial flora were almost identical to that of the normal vagina. The growth-stimulating substance affecting the epithelium may be derived from the surrounding connective tissue *in vivo* as well as *in vitro*.

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ANATOMICAL STUDY AND CLINICAL CONSIDERATION OF THE FASCIAE LIMITING URINARY EXTRAVASATION FROM THE PENILE URETHRA

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ANATOMICAL and pathological observations, in general have been a companion to the progress of surgery. In this report we are primarily concerned with the anatomy of the fasciae involved in the extravasation of urine from the penile urethra. In addition on the basis of our findings the two generally accepted theories dealing with the mechanism of urinary extravasation will be discussed.

The spread of extravasated urine from the penile urethra is limited by the extent and attachments of the fascial layers of the penis, perineum, scrotum and abdominal wall. Since the deep penile fascia of Buck is one of the first fascial layers limiting the spread of extravasated urine, a more complete description of this fascia is desired than is found in the literature at present. Although the descriptions and diagrams or pictures of this fascia given in the accounts by Buck (1848), Wesson (1923 and 1927), Young (1926), Hinmann (1935), Callander (1939), Culp (1942), Finestone (1941 and 1943), and in many standard textbooks of anatomy illustrate most of the connections and relations of Buck's fascia, many of these accounts are still incomplete. This is true particularly in regard to the relation of this fascia to the corpus spongiosum (cavernosum) urethrae, the *limb* bulbocavernosus and ischio-cavernosus, the dartos layers of the penis and scrotum, external spermatic fascia, the suspensory ligament and the deep layer of the superficial fascia of the abdominal wall.

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HISTORICAL BACKGROUND

Although the fasciae of Scarpa, Colles, and Buck have been described and illustrated many times before, there are some anatomical and clinical features that remain to be clarified. In order to bring about a better understanding of these fasciae a brief survey of their historical background will be presented.

The name of Scarpa (Fig. 1) apparently became associated with a layer of fascia over the lower part of the ventral abdominal wall on the basis of his original work on hernia. This work, published in Milan in 1809, consists of five memoirs with ten engravings (atlas folio). Our attention is to be centered upon *Memoria prima* of his *Sull'ernia inguinale e scrotale* (p. 2) in which he states:

"L'aponeurosi dell' obliquo esterno muscolo per certo tratto sopra dell' arco femorale e dell' anello inguinale è ricoperta da uno strato sottile della tela aponeurotica del muscolo fascialato, del quale strato una parte si stende di qua dall' anello sul muscolo cremastero, che accompagna nella scrotola non si confonde e si perde nel tessuto cellulare che unisce l'esterna superficie del cremastero col dartos. L'altra parte si spiega verso il fianco."

("The aponeurosis of the external oblique muscle for a certain space above [superior to] the femoral arch and inguinal ring, is covered by a fine layer of the aponeurotic sheath of the muscle covering of which one part is extended from here to the ring over the cremasteric muscle which it extends into the scrotum where it is fused [intermixed] and loses itself in the cellular aponeurotic web which unites the external surface of the cremaster with the dartos the other part lifts itself against the flank.")

The illustrations from Scarpa's original work on scrotal hernia (Figs. 3a and b) show the fascial layers distended by viscera and it is difficult to ascertain clearly whether he referred to the fascial layer which now is associated with his name. Eycleshymer (1917) and Castiglioni (1941) designate the cremasteric fascia as Scarpa's fascia.



Fig. 1. Antonio Scarpa, 1747 (?)–1832.

Sir John Struthers (1854) further clarified the use of the term *fascia of Scarpa* (p. 231)

Although the description of this fascia by Scarpa, as contained in the translation of his work on the hernia, is very brief and imperfect, I shall retain the title *fascia of Scarpa*, as it is preferable to have a short specific name for a part to which frequent reference is to be made.

Struthers continues

—the fascia of Scarpa has another important connection, in its continuation around the spermatic cord, towards the perineum, here it becomes continuous with the true superficial fascia of that region, and to avoid confusion and derive advantage from the use of short specific name I am in the habit of calling it the fascia of Colles, and if anatomists would agree to call these two fasciae the fascia of Scarpa and the fascia of Colles, it would save much perplexity to the student.

In regard to the rôle of Colles' fascia in urinary extravasation we again quote Struthers (p. 236)

"By introducing a blow pipe, or bellows through an opening in the fascia of Colles in front of the anus, where the air

will readily force its way forwards, and inflate the scrotum, but does not reach backwards or sideways.

Two years after the work of Scarpa on the hernia, Colles (Fig. 2) published his *A Treatise on Surgical Anatomy* in which he states, "This fascia (now known as Colles' fascia) although on a superficial view appears continuous with the fascia of the muscles of the thigh, will be found on close examination to attach itself very firmly to the ramus of the ischium and pubis. Struthers (p. 235) was aware of the fact that a continuous membrane was formed by fasciae of Scarpa and Colles and that the latter fascia was attached to the inguinal diaphragm.

Fig. 2. Abraham C. Colles, 775-843.

In 1848 Buck (Fig. 4) published "A New Feature in the Anatomical Structure of the Genitourinary Organs not hitherto Described. In his work particular

*Colles did not illustrate this part of his work on anatomy—see pp. 2-120.



Fig. 3. Reproductions of Plate I A and II B from Scarpa's *Sull' ernia*. The legends neither state nor suggest

that Scarpa observed the deep layer of superficial fascia over the ventral abdominal wall now bearing his name.

emphasis is placed on urinary and certainly the joint is well put for this is the first fascial layer to be involved when urine leaves the urethral channel under pathological circumstances. Buck states (p 367)

"The anatomical structure in question consists of a distinct membranous sheath investing the penis in the manner to be described, (forming one continuous membrane enclosing the corpus cavernosum¹ in its cavity and embracing the corpus spongiosum urethrae between two layers) and forming a continuation of the suspensory ligament above and the perineal fascia below" (Fig. 5)

Moreover to bring forth Buck's comment on extravasation we again quote

"The texture and connections of this fascia (Buck) will serve to explain many of those phenomena attendant on the effusion of urine into the perineum by rupture or ulceration of the posterior part of the canal of the urethra."

MATERIAL AND METHODS

Since Buck's, Scarpa's, Colles' and the dartos fasciae are of interest both to the anatomist and urologist, a re-evaluation of these fasciae was made in an attempt to complete the description of their structure and connections. This work was done with particular reference to the relations of Buck's fascia in limiting the spread of extravasated urine. Therefore, studies were made first on the lower abdominal, penile, scrotal and perineal fascial layers of 5 adult, embalmed cadavers. Additional studies were made on 4 cadavers in which an incision was made through Scarpa's fascia, above the mons pubis, and compressed air (4 lbs. pressure) forced beneath this layer to separate it, and the layers continuous with it from the other fascial layers of the lower abdominal wall, penis, scrotum, and urogenital triangle of the perineum. The mucosa of the penile urethra bulbous portion, was perforated by a small hooked-shaped scalpel through a Young's urethra scope (No. 24 French). Subsequently pigmented liquid latex or vinylite was injected with a Janet Frank's bladder syringe into the perforated urethra, by way of the prostatic urethra to simulate the course of urine flow and of extravasation. The fossa navicularis was occluded by compression. Following injection these cadavers were embalmed. The use of liquid pigmented injection material allows one to follow the course of extra-

¹Note while Buck considered the corpus cavernosa penis as single body anatomically they are considered as two separate bodies.



Fig. 4 Gurdon B. Buck, 1807-1877

vasation and to dissect the fascial layers involved.

To support the studies made on the normal cadavers and simulated extravasation cases, an embalmed body from a case with extravasation was injected similarly with pigmented liquid latex. A brief summary of this patient's history is

G. K., S. M. H. No. 109108, a 60 year old, white male was admitted to this hospital November 30, 1912. In 1909 he had gonorrhea and had difficulty passing urine at intervals ever since. At the time of admission he had symptoms of extravasation of 8 days' duration. He also had had a respiratory infection and cough more than a week previous to admission. His abdomen was reddened from the symphysis up to the umbilicus, the redness being more marked on the right than on the left side. There was swelling beneath this area. His penis was blue, black and gangrenous and tender to touch. The scrotum was swollen reddened and tender. This patient was sent to the operating room immediately upon admission and the gangrenous area of the penis was removed. Multiple incisions and drainage wounds were made over the penis, scrotum, abdomen and perineum. He died the day following admis-

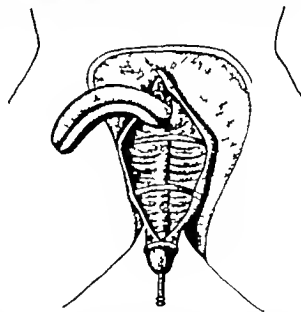


Fig. 5. Reproduction of plate from Buck's original paper showing the relations of "Buck's fascia" to the corpora. A Dissection of the sheath of the penis, showing the corpus cavernosum, enucleated from the sheath, B, the sheath, split up through the suspensory ligament, of which it is a continuation C the relations of the sheath to the corpus spongiosum urethrae, one layer of which passes above, the other below it D its relations to the glans penis, to which the sheath adheres inseparably by its outer surface, while by its inner surface it caps the corpus cavernosum E, the dorsal arteries, veins and nerves, raised with the sheath.



Fig. 6. Penile portion of penis raised to show in tegument of the penis and scrotum.

sion (December 943) A clinical diagnosis of lobar pneumonia as given as the cause of death.

ANATOMICAL STRUCTURE OF FASCIAE

1. *Uninjected specimens* The continuity of fascial layers of the penis, scrotum, and urogenital triangle is shown in Figures 7, 8, 10, and 12 and Table II. The caudal continuations of Camper's and Scarpa's fasciae are thin and fused together to form the dartos fascia over the shaft of the penis and over the scrotum. The external pudendal vessels of the penis and the posterior scrotal vessels and nerves are embedded in the dartos fascia. Involuntary muscle fibers are enclosed in this fascia both in the scrotum and along the shaft of the penis (Fig. 7). In the perineum, the fasciae which formed the dartos layer separate from each other to become the subcutaneous fatty layer and the membranous layer (Colles' fascia) respectively (Figs. 8a and 9). The former layer can be traced into the ischioanal fossa where it is continuous with the adipose tissue of this fossa. The Colles' fascia is connected to the inferior ramus of the pubis and ischium and to the posterior inferior border of the urogenital diaphragm (Figs. 7, 8a and 9).

In the urogenital triangle, Buck's (the deep penile) fascia is attached to the inferior layer of the urogenital diaphragm and to the inferior ramus of the pubis and ischium. From these attachments Buck's fascia encloses the origins of the three components of the penis, with their respective muscles, in separate compartments—the bulb of the corpus spongiosum (cavernosum) urethrae

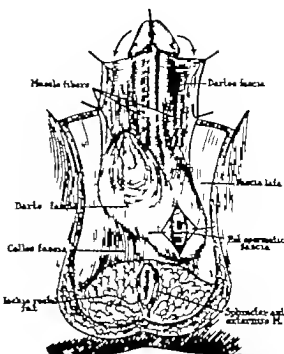


Fig. 7. Skin removed from penis, scrotum, and perineum to show the subjacent dartos fascia of the penis and scrotum. This fascia contains involuntary muscle fibers along the shaft of the penis and over the scrotum. The right half of the scrotum is retracted to show the continuity of the dartos fascia of the scrotum with Colles' fascia of the urogenital triangle. The dartos fascia is cut along the dorsum of the penis and reflected laterally as shown by arrows. The subjacent external spermatic fascia is exposed where the dartos fascia is cut over the left testis. The subcutaneous fatty layer of the urogenital triangle has been removed.

with the bulbocavernosus muscle in the central compartment, the corpus cavernosum penis and ischio cavernosus muscle of each side in a lateral compartment (Fig. 9). In the shaft of the penis Buck's fascia surrounds all three of these erectile bodies as a common layer in the form of a figure of 8, as previously stated by Wesson (1933). However a transverse septum of Buck's fascia separates the corpora cavernosa penis from the corpus spongiosum (cavernosum) urethrae the latter body being contained in a separate compartment along the ventral surface of the penis (Figs. 8b and 12). The bulbocavernosus and ischio cavernosus muscles are internal to Buck's fascia. They and their intrinsic fasciae become attached to and have part of their insertions in Buck's fascia along the shaft of the penis (Figs. 8a, 9, 10 and 11). Buck's fascia is external to and distinct from the tunica albuginea of the corpus spongiosum (cavernosum) urethrae and corpora

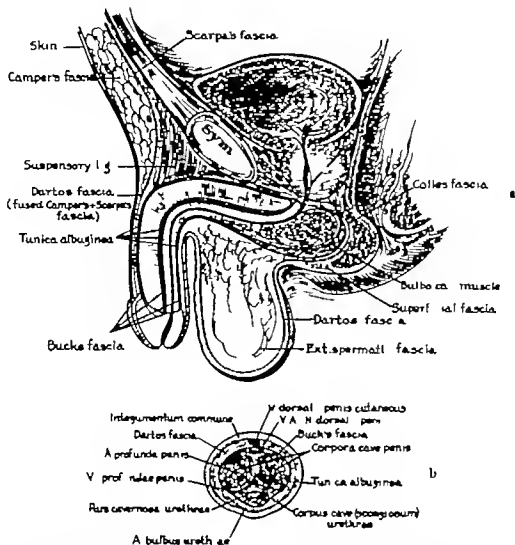


Fig. 8. a, above. Sagittal section of pelvis. Camper's and Scarpa's fasciae fuse to form the dartos fascia of penis and acrotum. The dartos fascia is continuous with subcutaneous fatty layer and with Colles fascia of the urogenital triangle. Buck's fascia is external to the bulbocavernosus muscle and to the tunica albuginea of the three vascular components of the penis. b, Cross section of the shaft of the penis. The relation of Buck's fascia to the dorsal vessels and nerves of the penis, the tunica albuginea of the erectile bodies of the penis and the compartment formed by Buck's fascia around the corpus spongiosum urethrae are shown in this section.

cavernosa penis. It is thickest along the dorsal surface of the penis that is the surface which is adjacent to the ventral abdominal wall and faces dorsally during erection. The deep dorsal vein arteries, and nerves of the penis and their branches are internal to Buck's fascia (Figs. 8b and 10). Smaller branches of these vessels and nerves penetrate and course in the tunica albuginea. This fascia becomes continuous with the suspensory ligament of the penis (Figs. 8a and 10) and fibers of the bulbocavernosus and ischio cavernosus muscles may be inserted in the suspensory ligament. In a few specimens there was a fusion of the dartos fascia and Buck's fascia at the beginning of the pendulous part of the penis.

2 *Injected specimens* A *Simulated extravasation* In these cases of simulated extravasation the surgical perforations were of varying depths rupturing only the penile urethra in 1 case where as the urethra, cavernosus tissue, tunica albuginea and Buck's fascia were ruptured in the other cases. As shown by the anatomical connections of Buck's fascia described and by the course of the pigmented material injected (Figs. 12 and 13) extravasated material from rupture of the penile urethra first enters and spreads in the cavernous tissue of the corpus spongiosum. In this way urine and other contents of the urethra may enter the vascular system (Fig. 13). Its further spread is then limited by the tunica albuginea around the

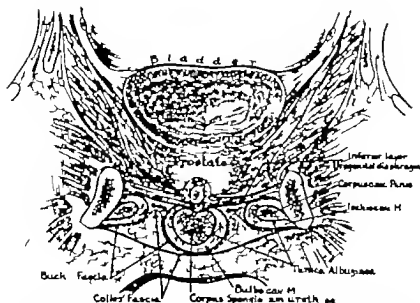


Fig. 9. Frontal section through pelvis and perineum. Buck's fascia forms three separate compartments around the erectile bodies and their muscles in the urogenital triangle of the perineum. Colles' fascia is superficial to Buck's fascia. The normal position of Colles' fascia is shown by the dotted line—beyond its position in extravasation cases is shown by the solid line.

corpus spongiosum. If the tunica albuginea is perforated, then the next limiting barrier is Buck's fascia. Since this fascia forms a separate compartment for the entire length of the corpus

spongiosum—from the glans to the bulb—the extravasation will be contained within the limits of Buck's fascia, filling and producing a swelling of this fascial compartment along the ventral surface of the penis. When Buck's fascia is ruptured, the extravasation spreads between the dartos fascia and Buck's fascia. While between these layers extravasation can spread backward into the perineum between Colles' and Buck's fascia—ventrally into the scrotum between the dartos fascia and external spermatic fascia and cephalad around the shaft of the penis beneath Scarpa's fascia over the abdominal wall (Table I). The fusion of the dartos fascia with Buck's fascia at the beginning of the pendulous portion of the penis described, in some cases may prevent the extravasation from spreading down the shaft of the penis. In all of these studies the injected material was outside of the external spermatic fascia in its course through the scrotum.

B True extravasation. The testes, from the cadaver of the patient with a case of true extravasation, were necrotic and could not be dissected as well as in the other cases. However as shown by the course of the injected material in this specimen the extravasation spread in the corpus spongiosum from the ruptured penile urethra. It then passed through the tunica albuginea of the corpus spongiosum and filled a dilated sac formed

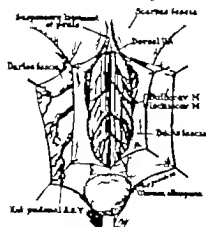


Fig. 10. The skin and Camper's fascia are removed to show the relation of Scarpa's fascia to the dartos fascia and the suspensory ligament to Buck's fascia. The dartos fascia is split along the midline and reflected laterally. The external podendal vessels are located in the dartos fascia. Buck's fascia is continuous with the suspensory ligament of the penis and is external to the deep dorsal vein, arteries, and nerves of the penis. Fibers of the bulbocavernosus and ischio-cavernosus muscles extend around the shaft of the penis internal to Buck's fascia.

in Buck's fascia along the ventral surface of the penis. A perforation in Buck's fascia allowed the extravasation to spread between Buck's fascia and the dartos fascia on the ventral surface of the penis. Further spread was found between Colles' fascia and Buck's fascia over the root of the penis between the dartos and external spermatic fascia of the scrotum and the dartos and Buck's fascia over the shaft of the penis. On the abdomen the extravasation was found between Scarpa's fascia and the aponeurosis of the external oblique muscle.

DISCUSSION

It becomes apparent after reading Eycleshymer (1917—62:47 and 47:47) and Castiglioni (1941—p 601) that some misunderstanding persists from the anatomical point of view as to the justification of applying Scarpa's name to the fascial layer with which it is now associated. This feeling has been strengthened by a statement of Struthers (1854).

Although the description of this fascia by Scarpa is very brief and imperfect, it is preferable to have a short specific name for a part to which frequent reference is made. In view of the foregoing data it is our recommendation that the name of Scarpa be continued to designate the superficial layer of deep fascia over the ventral abdominal wall.

In regard to the anatomical and clinical studies of Colles and Buck, we agree with most of their descriptions of the fasciæ which bear their names. However we have added some anatomical details to those of Buck.

Buck's fascia, by forming a closed compartment around the corpus spongiosum urethrae, is known to be one of the first fascial layers limiting the spread of urine extravasated from the penile urethra. However some of the published diagrams of Buck's fascia, do not show the transverse septum of this fascia forming a compartment around the corpus spongiosum urethrae. Nor do such diagrams clarify the relation of Buck's fascia to the bulbocavernosus and ischiocavernosus muscles.

Buck (Fig 5) did show the transverse septum of this fascia separating the corpora cavernosa penis from the corpus spongiosum urethrae and forming a compartment around the latter erectile body. He also demonstrated the relation of this fascia to the dorsal vessels and nerves of the penis and to the suspensory ligament and mentioned that this fascia may form three compartments around the erectile bodies in the perineum.

From the connections of Buck's fascia to the intrinsic fascia of the bulbocavernosus and ischiocavernosus muscles along the shaft of the penis to

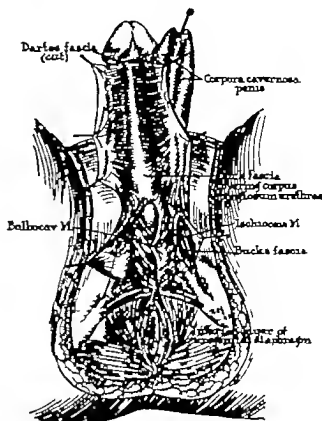


Fig. 11. Ventral view of dissected penis. The scrotum and the dartos fascia, cut at the base of the glans penis, have been removed. Buck's fascia has been cut along the dorsum of the penis and reflected laterally. The corpora cavernosa penis are dissected from the glans and corpus spongiosum urethrae and retracted to the side. Buck's fascia is cut and retracted over the bulb and over the left crus of the penis to show its relation to the bulbocavernosus and ischiocavernosus muscles respectively.

the suspensory ligament here demonstrated this fascia may be compared to a prolonged tendon or aponeurosis of insertion for some of the fibers of these muscles. The extent of the bulbocavernosus muscle in a negro cadaver dissected in our anatomical laboratory suggests this comparison. In

TABLE I.

Sequence of tissues involved in extravasation from the penile urethra.

1. Through urethral wall.
2. Into and through corpus spongiosum urethrae.
3. Through tunica albuginea of corpus spongiosum urethrae.
4. Into the space between tunica albuginea of corpus spongiosum and Buck's fascia. Buck's fascia may limit further spread and the extravasated urine may produce a swelling beneath this fascia, since Buck's fascia surrounds the corpus spongiosum urethrae.
5. Through Buck's fascia and between (a) Buck's and Colles' fascia of the perineum (b) Buck's and dartos fascia of the penis, and (c) dartos and external spermatic fascia of the scrotum.
6. Between Scarpa's fascia and deep fascia of external oblique aponeurosis of ventral abdominal wall.

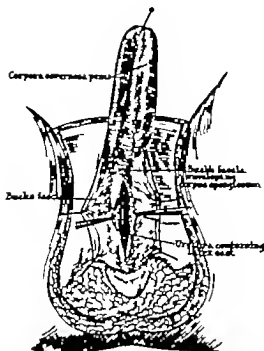


Fig. 2. Penis from specimen in which the urethra was perforated surgically. The dartos fascia and scrotum are removed. Buck's fascia is cut along the dorsum of the penis and reflected laterally. The corpora cavernosa penis with their tunica albuginea are reflected dorsally. Note that Buck's fascia forms a septum between the corpora cavernosa penis and the corpus spongiosum urethrae. In the distal part of the shaft of the penis, Buck's fascia, the tunica albuginea, corpus spongiosum, and dorsal wall of the urethra are cut to show the latex cast of the urethra.

this specimen fibers of the bulbocavernosus muscle extended around the shaft of the penis within Buck's fascia into the suspensory ligament—almost to the fibers of the external oblique aponeurosis.

As shown in these studies where the course of extravasated urine was simulated by injecting pigmented material into the urethra perforated by a scalpel the cavernous tissue of the corpus spongiosum becomes filled with the injected material. In this way infection entering a very vascular tissue may be introduced into the general circulation. The spread of extravasated material may be limited by the connections of Buck's fascia along the entire course of the corpus spongiosum—from glans to bulb—and then kept within this fascia along the ventral surface of the penis. When Buck's fascia is perforated the extravasation then may pass between Buck's fascia and the next external layer—Colles' fascia of the perineum—dartos fascia of the scrotum and

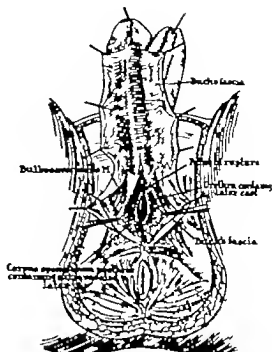


Fig. 3. Ventral view of dissected penis. The dartos fascia and scrotum are removed. Buck's fascia is cut along the dorsum of the penis and reflected laterally. The corpora cavernosa penis is separated from the corpus spongiosum and retracted to the side. Buck's fascia is cut over the proximal part of the corpus spongiosum and reflected laterally to show the relation of this fascia to the bulbocavernosus muscle. The tunica albuginea, part of the corpus spongiosum and the ventral wall of the urethra have been opened to show the latex cast in the urethra. Note point of surgical rupture of the urethra where injected latex extravasated and entered tissues of the corpus spongiosum.

penis and Scarpa's fascia over the abdomen, since the dartos layer of the penis and scrotum are continuous with Camper's and Scarpa's fasciae.

These anatomical studies hold a position of utmost importance clinically because they permit one to satisfy the two theories of the etiology of urinary extravasation from the penile urethra—namely hydrostatic and vascular changes associated with bacterial invasion. It is most probable that urinary extravasation proceeds on the basis of a combination of these two theories. Furthermore in the opinion of Finestone (1942) the contractions of the bulbocavernosus muscle and the external sphincter of the urethra and the act of micturition all contribute to the spread of urine and infection. Stricture formation also plays an important role. However Finestone (1942) found strictures in 19 of his 32 cases,

TABLE II.—STRUCTURE AND CONTINUITY OF FASCIAL LAYERS

Abdominal wall	Penis	Scrotum	Urogenital triangle	Anal triangle
<i>Campbell's fascia</i> Subcutaneous, superficial fatty layer	<i>Dartos fascia</i> Membranous. Contains involuntary muscle fibers. Located between skin and Buck's fascia	<i>Dartos fascia</i> Membranous. Contains involuntary muscle fibers. Located between skin and external spermatic fascia	Superficial, fatty layer between skin and Colles' fascia.	Superficial fatty layer and fat pad of ischioanal fossa.
<i>Scarpa's fascia</i> Deeper membranous layer—attached to iliac fascia below inguinal ligament			<i>Colles' fascia</i> Membranous. Attached to inferior ramus of ischium and pubis and to dorsal inferior border of urogenital diaphragm	
<i>Buck's fascia</i> Continuous with deep fascia of external oblique aponeurosis as suspensory ligament of penis. May contain terminal fibers of bulbocavernosus and ischioavernosus muscles	<i>Buck's fascia</i> Aponeurotic. Surrounds corpora cavernosa penis and corpus spongiosum urethrae in separate compartments. External to muscles of these erectile bodies. Internal to dartos fascia		<i>Buck's fascia</i> Aponeurotic. Forms three separate compartments around muscles and erectile tissues of penis. Attached superiorly to inferior layer of urogenital diaphragm and to inferior ramus of pubis and ischium	

whereas Culp (1942) found stricture in 32 of his 42 cases of urinary extravasation from the penile urethra.

In the extension of the urine from the urethral lumen itself we could agree with Wesson (1923) that Buck's fascia is not the impenetrable bulwark generally assigned to it. This fascia is best developed in the pendulous part of the penis and is much thinner where it covers the bulb of the corpus spongiosum and bulbocavernosus muscle.

Some comments are needed in considering the anatomical directions of urine flow in extravasation in relation to some of the findings by Finestone (1941) and in our study. When we injected air beneath Scarpa's fascia, in the suprapubic area, it traveled under the dartos of the penis and scrotum.¹ However air injected in the perineum beneath Colles' fascia as conducted by Struthers (1854) would travel in the perineum and inflate the scrotum. On the other hand the injection of the penis (corpora cavernosa) by Finestone (1941) limited the injected medium to the penis because it was held *in situ* first by the tunica albuginea and then by Buck's fascia.² This fits in too with

Finestone's view of vascular thrombosis and infectious thrombophlebitis (chiefly anaerobes) in the mechanism responsible for urinary extravasation.

The findings of Struthers (see 'Historical Background') suggest that if only the perineum and scrotum are involved then Colles' fascia might first be incised and then dissected up under the dartos of the scrotum before incision and drainage of this region. Furthermore, the reported anatomical studies in addition to our present work give some support to the opinion that if the extravasation of urine is extensive one might open Scarpa's fascia, after suprapubic cystostomy and then dissect under the dartos of the penis and scrotum. The necessary incisions for drainage could be made without damage to fascial layers and tissues not involved provided the tissue changes are not too marked.

CONCLUSIONS

The course of extravasation observed in studies on simulated extravasation from rupture of the penile urethra passes first through the corpus spongiosum (where it enters the vascular erectile tissue) and the tunica albuginea of the corpus spongiosum. Buck's fascia limits further spread and the extravasation may cause filling and distention of this compartment formed around the corpus spongiosum. After perforating Buck's fa

¹ Although the use of 4 lbs. air pressure in these studies exceeds the physiological pressure of extravasated urine, this pressure did not preclude artificial splitting of the fasciae studied. This conclusion was based on the comparison of the texture and extent of the fascial layers in animal cadavers compared to those from simulated extravasation cases.

² Finestone's other injection experiments, the course of the radio-opaque material injected into the superficial perineal pouch, was the same as our findings for pigmented liquid latex or vinylite injected into the surgically perforated urethra.

sia the spread is between Buck's and Colles fascia in the perineum between Buck's and dartos fascia around the penis between the dartos and external spermatic fasciae in the scrotum and between Scarpa's fascia and the deep fascia over the aponeurosis of the external oblique muscle over the abdomen.

Buck's fascia is a strong fibrous layer between the dartos fascia and tunica albuginea, which extends from the inferior surface of the urogenital diaphragm and inferior rami of the pubis and ischium around the shaft of the penis to the corona of the glans penis. It is external to the deep dorsal vessels and nerves of the penis and is continuous with the suspensory ligament. Each of the three erectile bodies of the penis with their respective muscles in the perineum are enclosed in a separate compartment of Buck's fascia. As the corpora cavernosa penis and corpus spongiosum urethrae approximate each other to form the shaft of the penis, all three erectile bodies and their muscles are encircled by a common layer of this fascia. A transverse septum of Buck's fascia separates the corpora cavernosa penis from the corpus spongiosum urethrae, enclosing the corpus spongiosum in a separate compartment along the ventral surface of the shaft of the penis. The bulbocavernosus and ischioavernosus muscles are inserted into the inner surface of Buck's fascia. This fascia may be compared to a prolonged tendon or sponenrosis of these muscles.

This study adds to the anatomy of the fasciae related to urinary extravasation and not only provides a basis upon which to explain the route and structures involved, but also helps to clarify the current theories dealing with the mechanism responsible for extravasation of urine.

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THE VALUE OF A NEW COMPOUND USED IN SOAP TO REDUCE THE BACTERIAL FLORA OF THE HUMAN SKIN

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THE war has again emphasized the primary importance to the individual of soap—the most commonly used chemical substance contacting the human skin. Attempts to produce a germicidal soap which would satisfactorily cleanse the skin and at the same time materially reduce its bacterial flora have in the past not been entirely successful. The germicidal value of soaps has been discussed by several authors (4). Another group of authors have devoted their attention to studies of the bacterial flora of the skin (7, 8, 9, 12).

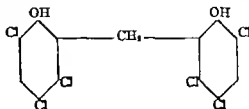
The primary object of our study was to investigate the germicidal action on the skin of the human hands and forearms of a new synthetic phenol 2,2-dihydroxy 3,5,6-trichloro-3,5'-dihydroxy-3,5'-hexachloro-diphenyl-methane (hereinafter termed G-11) incorporated in toilet soap. Preliminary studies determined the effect of G-11 upon the growth of certain micro-organisms. Further the human skin was tested for sensitivity to G-11. Finally we studied the effect of G-11 upon the bacterial flora of the hands and forearms of over 20 individuals completing over 125 series of washings.

The striking results we obtained in reducing and maintaining low bacterial counts on the skin surface as a result of the regular daily use of a new compound incorporated in ordinary toilet soap will, we feel certain, therefore, be of great importance in many fields, but especially in simplifying surgical scrub-up technique. MacKee,³ in commenting on our experiments, said "This seems a convincing result and it should be a useful soap. The bacterial results if corroborated are remarkable."

Price¹ has appraised the effectiveness of compound G-11 incorporated in soap as follows: "There can be little doubt, I think, that you have a product here which is effective in reducing the bacterial flora of the hands to a remarkable degree and one which may find a field of usefulness in the surgical preparation of hands."

GERMICIDAL ACTIVITY IN VITRO OF COMPOUND G-11 AND OF SOAPS CONTAINING COMPOUND G-11

Compound G-11 (2,2-dihydroxy 3,5,6-trichloro-3,5'-dihydroxy-3,5'-hexachloro-diphenyl methane) has the structural formula



Compound G-11 when tested in the form of its sodium or potassium salt is strongly bacteriostatic and bactericidal against *Staphylococcus aureus* and other gram positive cocci such as *Streptococcus hemolyticus* type C and *Streptococcus viridans*. Excess alkali does not interfere with this bactericidal action. The *Staphylococcus aureus* phenol coefficient of G-11 determined at 37 degrees C. by the Food and Drug Administration method (1) is approximately 125. The activity of G-11 is somewhat reduced in the presence of serum; it is also weaker in its action against gram-negative micro-organisms, such as *Escherichia typhi* and *Escherichia coli*. These facts were determined by numerous *in vitro* culture experiments including also the so called wet filter paper technique (1). Rabbit experiments to compare the bactericidal properties of soap containing 2 per cent of G-11 and a soap of identical composition without the G-11 were carried out in general the technique of J. S. Simmons being used (14). The results obtained showed that the G-11 soap while not sterilizing superficial wounds did produce a decided decrease in the bacterial count.

TESTS FOR SKIN SENSITIVITY

To test the allergic, irritating or sensitizing indices of G-11 we performed patch tests on more than 200 subjects.⁴ The procedure⁵ was to

¹More than 60 practically similar patch tests had been previously performed by H. J. C. Minsky, M.D., Passaic, New Jersey with entirely negative results.

²I have done 400 additional patch tests with G-11 with all negative results.—E. F. T.

Experimental project, University of Vermont College of Medicine, Burlington, Vermont.

³William S. Gump, U. S. Patent 2,250,480.

⁴Personal communication.

⁵Personal communication.

test each subject with (1) 0.5 per cent G-11 in petrolatum (2) 1 per cent G-11 in petrolatum.

The patch tests were applied in the usual orthodox manner and the tests were read 5 days later. All tests were negative. Ten days after reading the first tests, each patient was patch-tested at or about the same site to determine whether any sensitivity might have been produced. These patch tests were allowed to remain in place for 48 hours and were read at the end of 48 hours and negative, indicating that G-11 was nonirritating to the skin and was not a skin sensitizer. In addition, none of the subjects used for the washing experiments developed any evidence of skin irritation or dermatitis. A group of subjects have now used the soap containing G-11 for approximately 1 year with not a single instance of irritation despite the fact that included in this group were individuals with known allergies (asthma, hay fever and eczema).

DEVELOPMENT OF THE EXPERIMENTAL METHOD

Mercury compounds and phenols have been employed in soaps in attempts to increase their bactericidal activity. Phenols have proved to be ineffective and the mercurials, though efficient, hold the threat of possible toxicity and irritation. Furthermore the bacteriostatic action of mercury compounds must be taken into consideration, and it is quite possible that bacteriostasis was misadvised powers of soaps containing mercurials were reported. Mercuric chloride or potassium mercuric iodide solutions do not reduce the flora of the skin appreciably but paradoxically a sterile cutaneous surface may be produced. This phenomenon is, according to Price (12) due to the formation of a transparent "film" on the skin under which the bacteria are imprisoned. There, conditions are so suitable to life that multiplication takes place, the existing bacterial flora doubling every 30 minutes. When the "film" is broken up, the bacteria are released uninjured. The same was true of other mercurials tested.

Norton (1920) compared the effect of washing the hands with ordinary soaps and with germicidal soaps. Hampill (1928) found that the soaps apparently interfere with the action of the disinfectant rather than enhancing it. McCulloch has reviewed the literature on this subject and disavowing the advantages and disadvantages of bactericidally active chemicals to soaps. It has been thought that phenols have not been effective in the presence of soap because they form inactive salts with the alkali of the soap.

However G-11 apparently behaves differently. When G-11 is added to excess alkali only one of the two hydrony groups is neutralized by alkali, thus leaving the remaining group free. This may account for the activity of G-11 in the presence of alkaline soap. When incorporated in small amounts in soaps, compound G-11 exhibits the unusual property of retaining sufficient of its bactericidal activity to render such soaps germicidal. The behavior of G-11 in this respect is contrary to that of most other phenolic substances. Other properties of the soap such as detergency, lathering power, pH, etc. are not affected by the presence of compound G-11.

Price (13) devised a new test for the study of the bacterial flora of the apparently normal skin, showed that if a person scrubs his hands and forearms according to a standard technique for a given period the number of bacteria removed may be determined with reasonable accuracy by plating a sample of the soapy solution of rinsings obtained, incubating for 48 hours, and counting the number of colonies. If a series of basins is used and the hands and arms are scrubbed in each one for the same length of time in a perfectly uniform manner the bacterial flora of the skin is reduced at a constantly diminishing rate and a regular logarithmic curve may be plotted from the data. Deviations from this standard rate may be caused by other influences, like the use of bactericides or the wearing of rubber gloves. It is thus possible to evaluate quantitatively the effect of skin-degerming agents, such as germicidal soaps. Price's procedure as slightly modified by Pohle and Stuart (11) showed that rosin soap and active germicidally on the bacteria normally found on human skin than the usual commercial fatty soaps free from rosin.

Pohle and Stuart (11) called attention to Price's classification of the microbial flora of the hands as the transient flora and the resident flora. It has been observed that the former are readily removed by washing with soap and water whereas the latter are quite resistant to removal. Pillsbury and associates noted that after the seventh scrubbing most of the transient bacteria had been removed from the skin, the count in subsequent scrubblings remaining practically constant. Price (14) reported that none of the commercial toilet soaps used by him had any germicidal activity on the resident population of the skin, the only action of the soap being the mechanical removal of some of the organisms. Pohle and Stuart (11) when testing a germicidal solution carried on a series of washings, using the substances to be

tested in one or more of basins No 4 No 5 and No. 6 in a series of ten basins. The same method was used in testing coconut oil soap to which rosin had been added. They also gave air subtracts commercial soap containing rosin and asked them to wash with it at home and in the laboratory for 1 week. At the end of the week they washed according to the normal procedure using a control soap in all 10 basins. The curves obtained by plotting the count for the normal procedure before and after using commercial rosin soap for 1 week showed that both the transient and resident flora of the hands were materially reduced.

During our experiments, we used as subjects a group of people who washed certain definitely measured skin areas of the hands and forearms according to a standard technique based upon the Poble and Stuart (10) modification of Prince's method and improved by some refinements in technique that suggested themselves to us as we proceeded with the experiments.

For each subject 10 sterile basins were used, each containing 2000 cubic centimeters of freshly distilled water at 23-28 degrees C. The subject was instructed regarding the washing technique and carefully measured lengths of the hands and forearms (14 inches from the tip of the middle finger) were marked off with "wet proof" adhesive tape. Prince, Poble and Stuart, Pillsbury and associates merely indicated to the subject the point on the forearm to which the washing should be carried as otherwise the subject might vary the area scrubbed by more than an inch or two without realizing it and this would cause unfair variations in the counts, but we felt it more accurate to delimit the area definitely by taping. First a strip of tape 1 inch in width was applied encircling the forearm above and even with the mark. The distal edge of this strip was sealed with another strip one-half inch in width. At the first basin the subject moistened his hands in the water. Immediately afterward, by use of a stop-watch the subject was given 25 seconds in which to work up a soapy lather followed by a period of 75 seconds which was devoted to scrubbing (with out a brush) the test areas. This was followed immediately by a twenty-second period of rinsing in the basin. The subject moved to the next basin and repeated the procedure.

Within an interval not exceeding 2 minutes¹ after the subject finished at a basin two 0.1 cubic centimeter samples were removed from the soapy water in the basin and each was placed in a sterile Petri dish. Here we had changed the previously

recommended technique to remove the sample for plating in less than 2 minutes rather than to permit the entire series of washings to be completed (as had previously been done) before proceeding with the culturing. It should be apparent at once that if the basins with the soap solutions and bacteria are allowed to stand varying lengths of time before plating one is not testing the effect of the agent on the bacteria on the skin alone but also its effect on the bacteria while in the basin. Also the end of the pipette was wiped each time with a sterile swab to free the tip of soapy water before proceeding with the plating. These changes were considered as materially enhancing the accuracy of the counts. Approximately 15 cubic centimeters of melted (45°C.) beef heart infusion hormone agar pH 7.2 were added to each dish. The dishes were agitated to disperse the organisms and the media was allowed to solidify. They were inverted and incubated at 37.5 degrees C for 48 hours and then counted on a Quebec colony counter.

All glassware and other apparatus that came into contact with any of the test materials had been previously sterilized in an autoclave or hot air oven. The bars of soap were placed in petri dishes marked for identification.

As suggested by Poble and Stuart, the distilled water was used at a temperature of 23-28 degrees C. One tenth cubic centimeter samples of the water taken at random from several basins showed the count of the distilled water to be two to three cultivatable organisms per cubic centimeter. This figure was so low it apparently had no effect upon the possible error of the tests.

The basins used in the experiment were white enameled and measured 14 1/4 inches long 10 inches wide and 2 1/2 inches in depth. These basins were nested in groups of 10 enclosed in pounds pressure for 45 minutes in an autoclave. Media. The media used was beef heart infusion hormone agar 15 per cent.²

Soap Bars of toilet soap³—(1) those containing compound G-11 and (2) same without G-11 added namely the "blank" or control soap.

Alcohol In some of the experiments 70 per cent (by weight) ethyl alcohol was used. This was prepared as follows: To ethyl alcohol absolute, 280 grams add, distilled water 120 grams. Mix and stopper tightly to prevent loss of alcohol by evaporation.

Following the procedure previously described we performed hand washing experiments to de

¹For details on the preparation of media, consult the authors.
²Supplied by Glaxo-DeWitt, Inc., New York.

³Change made by us.

TABLE I.—AVERAGE COLONY COUNTS

Washing procedure	Basins									
					3	6	7	8	9	10
Initial washings, control soap used in all basins. Average of 5 subjects (Fig. 3)	3,71	3,87	3,96	3,7	3,57	3,793	3,317	3,045	979	1,09
Washings, per cent G-11 soap used in all basins. Average of 6 subjects (Fig. 4)	3,150	3,04	990	93	613	738	445	402	423	365
per cent G-11 soap used in basins 4, 5, and 6, control soap in all other basins. Average of 16 subjects (Fig. 5)	3,395	3,644	3,005	983	667	605	654	734	3,179	971
per cent G-11 soap used in basins 4, 5, and 6, control soap in all other basins. Average of 6 subjects (Fig. 6)	4,377	3,90	3,53	38	960		960	395	433	577
75 per cent ethyl alcohol used in basins 5, control soap in all other basins. Average of 6 subjects (Fig. 7)	4,49	17	3,63	300	33	83	43	986	977	335
75 per cent ethyl alcohol used in basins 5 for 30 seconds, then washed with control soap for 30 seconds and rinsed. Control soap in all other basins. Average of 6 subjects (Fig. 8)	4,540	3,900	3,156	3,156	700	67	650	47	476	130
per cent G-11 soap used in basins 5, control soap in all other basins. Average of 6 subjects (Fig. 9)	4,100	3,33	3,500	3,1	3,043	3,008	3,14	3,36	866	638

The counts as shown are given in thousands.

termine the practical germicidal action of soap containing G-11 on the human skin. Farther in order to investigate the possibilities of G-11 soap from the standpoint of practical application to operating room personnel, we thought that it would be well to study the efficiency of this soap in surgical scrub-up technique.

RESULTS OF EXPERIMENTS

1. *Preliminary studies* The obtained results indicating the average colony counts per basin for each procedure are given in Tables I and II and Figures 1 to 8. Charts and graphs showing the performance of each subject are available but are not included in this report. For the convenience

TABLE II.—AVERAGE COLONY COUNTS

Washing procedure	Basins									
			3	4	5	6		8	9	10
Washings, control soap used in all basins. Average of 6 subjects (Fig. 1)	3, 30	47	3,433	3,008	1,793	3,577	3,393	3,730	3,3	1,143
Average of 5 subjects who had used control soap for period of week. Control soap used in all basins (Fig. 4)	3, 13	3, 3	3,07	3,60	3,07	3,30	3,433	3,660	1,770	1,303
Average of 5 subjects who had used per cent G-11 soap for a period of week. Control soap used in all basins (Fig. 4)	3,00	73	3,3	3,07	3,73	3,07	3,3	3,3	3,17	30
Washings, control soap used in all basins. Average of 6 subjects (Fig. 5)	3,644	3,316	3,743	3,390	3,79	3,65	3,04	3,04	716	731
Average of 6 subjects who had used control soap for period of week. Control soap used in all basins (Fig. 5)	3,333	3,33	3,300	3,400	3,393	3, 3	3,73	7,46	773	3,30
Average of 10 subjects who had used per cent G-11 soap for period of week. Control soap used in all basins (Fig. 5)	34	73	43	37	67	46	30	43	33	36
Initial control soap washings. Average of 6 subjects (Fig. 6)	3,343	3,028	3,430	3,330	3,082	300	706	744	743	306
Final control soap washings after the 6 subjects had used per cent alkali soap routinely for week (Fig. 7)	3,130	3,318	3,04	990	905	730	3,17	6 3	7	307

The counts as shown are given in thousands.

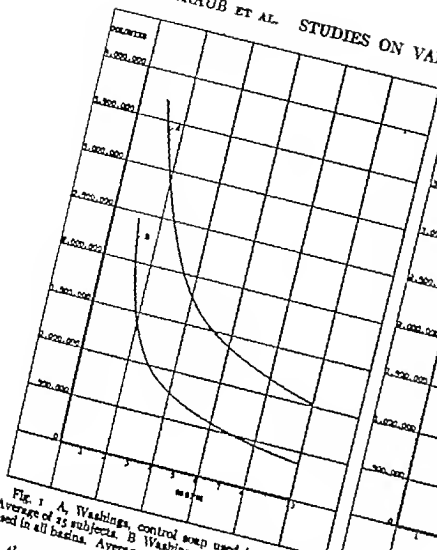


FIG. 1 A, Washings, control soap used in all basins. Average of 25 subjects. B, Washings, 4 per cent G-11 soap used in all basins. Average of 6 subjects.

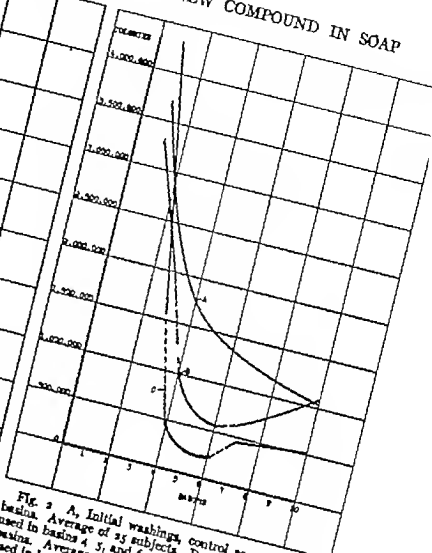


FIG. 2 A, Initial washings, control soap used in all basins. Average of 25 subjects. B, 2 per cent G-11 soap used in basins 4, 5, and 6. C, 4 per cent G-11 soap used in basins 4, 5, and 6. Control soap used in all other basins. Average of 6 subjects.

of the reader averaged smoothed curves were drawn as the actual counts of each basin can be found in the tables.

We have found in a large number (25 subjects) of control soap washings (Fig. 1) that there is a rather steep drop corresponding with the removal from the skin of the transient flora in the first few basins followed by a leveling off of the curve in the remaining basins concerned chiefly with the resident flora. This agrees with the findings of Price, Pohle and Stuart, and Pillsbury and associates. For comparison 2 per cent G-11 soap was used in all 10 basins a steeper decrease of the bacterial counts is noted from basin 1 to basin 2 as well as a greater comparative percentage drop in all basins.

Another series (Fig. 2) shows that when 2 per cent G-11 soap was used in basins 4, 5 and 6, there was some drop in the number of bacterial colonies cultured from each of these basins. Soap containing 4 per cent G-11 was tried in the same manner the drop of the bacterial counts was somewhat greater. This effect was not pro-

nounced enough to warrant the recommendation of using such a concentration because in the late work, regular use of soap containing a per cent of G-11 gave extremely low counts.

A third series of observations (Fig. 3) show a comparison of the effect of 2 per cent G-11 soap and the effect of 70 per cent (by weight) ethyl alcohol when these substances were used in basin 5. As there was a considerable increase of the bacterial count from basin 5 when alcohol alone was used to basin 6 where soap was again applied, the reason for the drop might be that alcohol is not as effective as soap in removing bacteria from the skin, as suggested by Cronwell and Lefler. When alcohol is followed by scrubbing with control soap in the same basin more organisms are removed than with alcohol alone, further substantiating the view of Cronwell and Lefler. These authors have found that some chemicals, such as ethyl alcohol and potassium alum, have a hardening action on the skin surface.



Fig. 3. A, Seventy per cent ethyl alcohol used in basin 5. Control soap used in all other basins. Average of 9 subjects. B, Seventy per cent ethyl alcohol used in basin 5 for 30 seconds only followed by washing with control for 3 seconds. Average of 6 subjects. C, Two per cent G-11 soap used in basin 5. Control soap used in all other basins. Average of 9 subjects.

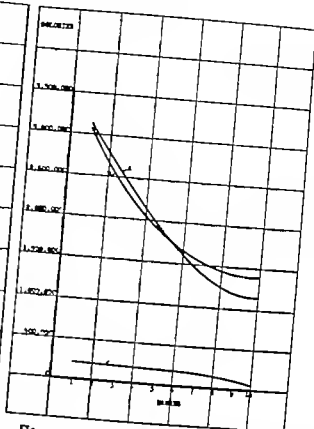


Fig. 4. A, Initial washings, control soap used in all basins. Average of 6 subjects. B, Control soap used in all basins. Average of 3 subjects who had used control soap for the period of one week. C, Control soap used in all basins. Average of 3 subjects who had used 2 per cent G-11 soap for period of one week. Figures indicate that resident level was reached practically from second basin.

subsequent washing less effective. Alum 10 per cent, aqueous, though not germicidal, gives as good a "bacterial destruction" curve as 70 per cent alcohol, since few bacteria can be washed off after its use. As many antiseptics have a hardening or a softening effect on the skin that might influence the results by this method of testing, these factors should be considered in any comparative evaluations.

Our most encouraging results (Table II) were obtained as follows:

Six subjects washed the skin test areas using control soap in all 10 basins. Three of the subjects were given bars of 2 per cent G-11 soap and the remaining 3 were given bars of control soap. Both groups were instructed to use these bars of soap in all washings such as hand washing, washing any part of the body, washing dishes, etc., for 1 week. At the end of this period all of the sub-

jects washed again with control soap in all basins. Those subjects who had been using the control soap for 1 week showed counts closely following the initial control soap curve (transient and resident portions of the curve being easily identified). The subjects who had been using the 2 per cent G-11 soap for 1 week gave remarkably low counts, the figures indicating that the resident level had been reached practically from the second basin on, and this new resident level was a small percentage of the resident counts indicated in the control series (Fig. 4).

These extremely low counts induced us to repeat this experiment with a larger group of subjects. Ten persons who used 2 per cent G-11 soap regularly for 1 week again showed a great reduction of the bacterial flora of their skin (Fig. 5). It also was thought to be of interest to compare a soap containing a mercury compound with the

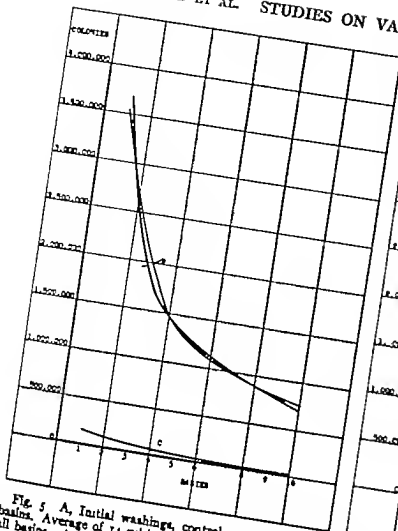


Fig. 5 A, Initial washings, control soap used in all basins. Average of 14 subjects. B Control soap used in all basins. Average of 4 subjects who had used control soap for a period of 1 week. C, Control soap used in all basins. Average of 10 subjects who had used 2 per cent G-11 soap for a period of 1 week.



Fig. 6 A, Initial washings, control soap used in all basins. Average of 35 subjects. B Colony counts on one subject who had used 2 per cent G-11 soap for a period of 1 week. Control soap used in all basins.

2 per cent G-11 soap. Two per cent neko soap which contains 2 per cent of mercuric iodide as a germicidal agent was selected for this experiment. Three subjects were given bars of control soap and 6 subjects received 2 per cent neko soap. All were requested to use these soaps in all washings for a period of 1 week at the end of the week, the bacterial flora of their hands and forearms was determined by the standard 10 basin washing with control soap. The counts are shown in Fig. 7. Apparently the regular use of 2 per cent neko soap does not give a significantly greater reduction of the bacterial flora of the skin than the ordinary toilet (control) soap.

One case of particular interest (Fig. 6) is that of one subject who was included in the group using 2 per cent G-11 soap for 1 week following and preceding routine control washings. He had just come from football practice when he appeared for the final control soap washings and his hands

were visibly soiled. Upon examination of the colony counts from the ensuing series of washings we noted that the first basin gave a count of 300,000 colonies. This count is only slightly higher than the average and much lower than had been expected considering the dirty hands of this subject. The curve then sharply descended and flattened out to the typical level found in the other subjects using the same washing program.

Another interesting episode had to do with the interruption of control soap hand washing periods by surprise blackouts which came 2 weeks apart. It happened that when the laboratory lights went out on both nights the same subject had reached the same basin (8th) in the series of washings and it was necessary for him to stand with his arms wet in contact with air for 20 minutes. Due probably to the softening effect of water on his skin, the counts in the first basins after scrubbing was resumed rose to remarkable heights (1st night 6280,000 and 2nd night, 6450,000). This close agreement of the counts encouraged us.

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Fig. 7 A, Initial washings, control soap used in all basins. Average of 4 subjects. B, Control soap used in all basins. Average of 6 subjects who had used 1 per cent pecto soap for period of week. C, Control soap used in all basins. Average of 3 subjects who had used 1 per cent G-1 soap for period of week.

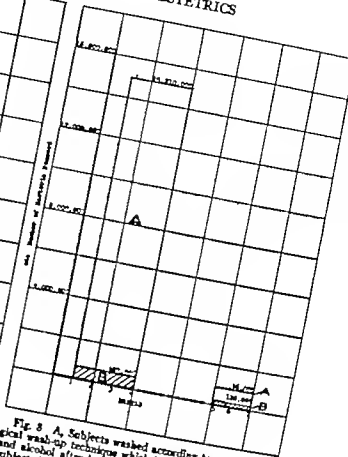


Fig. 8 A, Subjects washed according to a routine surgical wash-up technique which included the use of iodine and alcohol after basin 4. B, Results of washings after subjects had used 1 per cent G-1 soap for week. Here the surgical wash-up technique was modified by substituting alcohol. Forty-five minutes those elapsed between basins 4 and 5. During this period subjects wore sterile rubber gloves and manipulated surgical instruments.

greatly with respect to the apparent accuracy of the experimental method.

In general, the above experiments show that three 3-minute washings or even ten 3-minute washings with 2 per cent G-11 soap had slight effect in depressing the bacterial flora of the skin as compared with the great reduction noted after 1 week's regular use of the same soap. Obviously instantaneous killing of the bacteria takes place to a small degree only the effect of 2 per cent G-11 soap apparently is cumulative.

2. The use of 2 per cent G-11 soap in a surgical scrub-up technique. The surgical scrub-up procedure was simulated in that college students were used as subjects. In some instances basins of still water were used for rinsing and in other instances running water was used.

As a control experiment we first had 3 of our subjects wash according to the routine surgical scrub-up technique in use at the Mary Fletcher

Hospital in Burlington, Vermont. After the subjects had done this, they donned sterile sleeves and sterile rubber gloves and were asked to manipulate surgical instruments for a period of 45 minutes. At the end of this period the sleeves and gloves were removed and the subjects washed by our regular technique for 3 minutes in each of three basins of freshly distilled water. An exact account of the scrub-up technique as used follows.

The usual skin test areas were marked off with wet-proof adhesive tape and the subject was instructed on the importance of observing strictly aseptic technique. He then began to wash. Basin 1. The subject scooped up hospital soap¹ and washed his hands only for 30 seconds. He then rinsed in the basin for 20 seconds.

¹ A special soap prepared from caustic potash and lathered off. It contained no alcohol.

TABLE III.—AVERAGE COLONY COUNTS—SURGICAL SCRUB-UP TECHNIQUE

Washing procedure	Basins									
			3	4	5	6	7	8	9	
Standard hospital surgical scrub-up technique. Average of 3 subjects (Fig. 8)	3, 63	167	6,837	2,852	81	33	00			
Modified surgical scrub-up technique after routine use of 2 per cent G-11 soap for week. Average of 3 subjects (Fig. 8)	90	73	233	13	60	35	3			
Routine surgical scrub-up technique—rinsing water used. Average of 3 subjects (Fig. 9)	6,180	5,750	8,470	9,040	4,05	530	850	930	470	470
Routine surgical scrub-up technique—Iodine and alcohol omitted, control soap used instead of hospital soap. Average of 3 subjects (Fig. 9)	7,070	4,130	6,750	3,070	1,950	2,000		1030	70	1, 60
Standard technique using control soap. One bath only to arrive at transient level. This immediately preceded the distribution of bars of 2 per cent G-11 soap	6.3									
Routine surgical scrub-up technique omitting iodine and alcohol and using control soap. Two subjects had used 2 per cent G-11 soap for previous week (Fig. 9)	550	370	5	160	165	440			45	35

The counts as shown are given in thousands of colonies per bath.

Basin 2. The subject picked up a sterile brush wet with hospital soap and then washed the skin test areas of one limb successively scrubbing the backs and fronts of each digit, the palms and wrists the knuckles, and the forearms for a period of 3 minutes and rinsed 20 seconds.

Basin 3. The subject repeated the performance of basin 2 on the other limb again washing 3 minutes and rinsing 20 seconds. At this point the subject put aside the brush laying it in a sterile Petri dish cover and cleansed his nails with the point of a nail file and an orange stick. No time limit was put on this action.

Basin 4. All the test areas of both limbs were scrubbed with the brush soap being used as needed for a period of 4 minutes, devoting half of the time to each limb. The subject rinsed for 20 seconds and discarded the brush.

The ends of the digits to the distal interphalangeal joints were dipped into half strength tincture of iodine and withdrawn at once. The hands were briefly rinsed in 75 per cent (by volume) ethyl alcohol which was slightly tinged with iodine, and the arms were raised to allow the excess alcohol to run down the forearms. The subject wiped his hands and arms with a sterile towel pulled on sterile muslin sleeves powdered his hands with sterile talc and put on sterile rubber gloves.

The subject manipulated surgical instruments for a period of 45 minutes. The rubber gloves were aseptically removed and the subject washed in basins 5, 6, and 7 2 minutes in each without a brush and using a bar of control soap.

When the subjects had completed the foregoing experiment they were sent home with bars of 2 per cent G-11 soap to use routinely during the following week. Seven days later they again scrubbed by a method similar to the above but altered so that no germicidal materials were used. Bars of control soap were substituted for hospital soap and the tincture of iodine and alcohol were omitted. A basin of freshly distilled water was substituted in place of the alcohol rinse after basin 4.

The obtained results may be seen in Table III and Figure 8. The number of bacteria removed from the hands and arms by washing in basins 1 to 4 were added together also the number in basins 5 to 7. In the case of the routine surgical wash up technique, the count in basin 5 determined 45 minutes after the use of the iodine dip and the alcohol rinse, is quite low thus showing that this scrub-up method appears to be exceedingly trustworthy. Figure 8 further demonstrates that the regular use of 2 per cent G-11 soap over a period of 1 week prior to the scrubbing enables the washer to reach the resident level of bacterial flora practically at the start so that the surgical scrub-up time could be greatly shortened under these conditions. It is also to be noted that the count of the group using the standard scrub-up technique was several times higher in basin 5 (the first basin after the gloves were removed) than that shown after the routine use of 2 per cent G-11 soap. In the latter case this low count was reached without the benefit of either iodine or alcohol.

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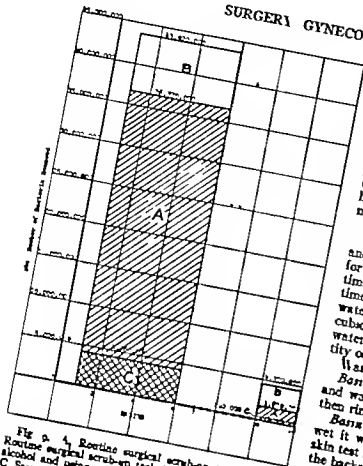


Fig. 4. Routine surgical scrub-up technique. B, alcohol and using control soap instead of hospital soap. C, Same scrub-up as B after subjects had used 3 per cent G-11 soap routinely for 1 week. Forty-five minutes elapsed time between basins 6 or 7 and 8. During this period subjects wore sterile rubber gloves and manipulated surgical instruments.

An objection may be raised to the fact that runnings were not made in running water. It is also realized that the subjects began to use 3 per cent G-11 soap routinely immediately after the use of iodine and alcohol. However we believe that this had no appreciable effect upon the results according to Price, 1 week is sufficient to re-establish the normal count of the bacterial flora and undoubtedly the regular use of the 3 per cent G-11 soap caused a great reduction in the number of bacteria which were removed by scrubbing.

In order to eliminate these possible objections, a second series of 3 experiments was carried out. They differed chiefly from the previous tests in that running sterile distilled water was used for washing and rinsing and that 2 weeks elapsed between the application of alcohol and iodine and

the start of the use of 3 per cent G-11 soap routinely for 1 week.

The results of this second series are shown in Table III and Figure 9. The number of bacteria removed in basins 1 to 6 and 8 to 10 were again added together. Basin 7 was omitted from graph A in order to have a better comparison with experiments B and C where the procedure with ex (alcohol-iodine dip) was not applied. In the table, however the count for basin 7 of the first experiment is given.

The procedures applied were as follows:

All water used in this series was running water and was used as needed during the series, whether for lathering, scrubbing or rinsing. A reasonable time was allowed for rinsing but a stop-watch time was not held on this procedure. The running water flowed at the rate of approximately 2000 cubic centimeters in 20 seconds. The amount of water used in each basin was the standard quantity of 2000 cubic centimeters.

Washings of first experiment

Basin 1. The subject scooped up hospital soap and washed his hands only for 30 seconds. He then rinsed his hands in running water.

Basin 2. The subject picked up a sterile brush, wet it with hospital soap and then washed the skin test areas of one limb successively scrubbing the backs and fronts of each digit, the palms and wrists, the knuckles and the forearms, for a period of 3 minutes, and rinsed the areas.

Basin 3. The subject repeated the basin 2 performance on the other limb again washing 3 minutes and rinsing the areas.

Basin 4. At this point the subject discarded the brush and cleansed his nails with a nail file and attended to the cuticles with an orange stick. Sufficient time was given to enable the subject to do this thoroughly but stop-watch time was not taken. The subject then rinsed both hands as well as the file and the stick.

Basin 5. The test area on one limb was scrubbed with a fresh sterile brush, soap being used as needed for 3 minutes, and then this limb was rinsed.

Basin 6. The subject repeated the basin 5 performance on the other limb using the same brush, washing for 3 minutes, and then rinsing this limb. The brush was then discarded.

Basin 7. The ends of the digits to the distal interphalangeal joints were dipped into half strength tincture of iodine and withdrawn at once and allowed to dry briefly. The hands were thoroughly rinsed in 75 per cent (by volume) ethyl alcohol, and the limbs were raised to allow the excess alcohol to run down the forearms. The

subject then washed his test areas with control soap according to standard technique and the rinsings were collected in this basin. The subject then wiped his hands and wrists with a sterile towel, pulled on sterile muslin sleeves, powdered his hands with sterile talcum powder and put on sterile rubber gloves.

The subject then manipulated surgical instruments for a period of 45 minutes.

Basins 8, 9 and 10 The rubber gloves were aseptically removed, and the subject washed in basins 8, 9 and 10 two minutes in each, according to standard technique without a brush and using control soap.

When alcohol and iodine and hospital soap were used approximately the same results were obtained as in the similar previous experiment (Fig. 8) except that the counts were elevated all the way through, perhaps due to the running water being used in rinsing and to the warmer weather.

When in the second experiment the alcohol and iodine were omitted and the control soap substituted for the hospital soap the colony counts after removal of the gloves were about twice as high as those of the regular surgical scrub-up technique.

The final experiment involved the omission of the alcohol and iodine and the use of control soap subsequent to a week's use of 2 per cent G-11 soap routinely. The counts obtained both before the gloves were put on and after their removal were much lower than corresponding counts in the experiment in which hospital soap and alcohol and iodine were used.

Our findings do not confirm Price's observation regarding the great increase in bacterial counts as a result of wearing rubber gloves. However it seems reasonable to presume that a surgeon under the mental strain and physical exertion of an operation would sweat much more than did our subjects, and this added moisture might enhance bacterial growth and possibly might account for the difference between Price's and our results.

SUMMARY AND CONCLUSIONS

1 Two per cent dihydroxyhexachloro diphenyl methane (G-11) incorporated in toilet soap enabled individuals to maintain an exceedingly low bacterial population on the skin of the hands and forearms.

2 Compound G-11 was non-irritating to the skin as judged by more than two hundred patch tests. These were repeated on the same subjects after 10 to 14 days and were again found to be negative, showing that no sensitivity of the skin

had been produced by the first tests. Subjects using 2 per cent G-11 soap regularly for 1 year have shown no evidence of irritation.

3 Our hand washing experiments (121 in individual series of washings) indicate that the most significant results were obtained by the regular routine use of 2 per cent G-11 soap. The evidence indicates that the regular use of toilet soap containing compound G-11 in a concentration of 2 per cent has such an effect on the bacterial flora of the human skin that the so called resident bacteria are decidedly and permanently (as long as this soap is used) reduced in number. An individual using this soap regularly has a lower resident count after 2 minutes of washing than an individual who washes for 20 minutes with ordinary toilet soap. The striking bactericidal effects obtained by daily use of toilet soap containing compound G-11 shown in Figure 4, compared with regular use of ordinary or control soap and neko soap indicate its value.

4. These results lead us to conclude that the daily use of a soap containing compound G-11 would enable a surgeon or operating room attendant to maintain an extremely low resident bacterial population on his skin.

5 This has suggested the possibility of shortening the routine preoperative scrub-up procedures and perhaps the elimination of use of irritating germicides without any sacrifice of skin cleanliness.

6 Regular use of soap containing compound G-11 according to our experiments, should reduce the probability of infection following skin abrasions and superficial wounds. This point might be of value in the hygienic care of members of the armed forces. Attendants of wounded in front line areas where lengthy surgical scrub-up routines which include the use of alcohol and iodine may be out of the question could nevertheless feel that the resident bacterial populations on their hands were at an exceedingly low level.

7 The economy suggested by the omission of the alcohol and iodine rinse may be an important factor especially now when they are not readily obtainable.

8 The use of G-11 either in soap or in other vehicles for protection against skin infections from barber shops, beauty parlors, hair follicle infections from cutting oils, et cetera, is suggested.

NOTE.—No special mention has been made in this article about the method of incorporation of G-11 into soap because in the case of cake soaps the compound would have to be incorporated at the time of manufacture. In the case of liquid soap, all that would be necessary would be to add 2 per cent of the compound G-11 to the liquid soap and thoroughly mix. Due to wartime restrictions, soap containing G-11 cannot be made available at the present

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time by Glaxo-Deiwaana, Inc., except for experimental purposes or clinical trials. The compound, of course, can be incorporated into any soap at the time of manufacture by simply adding it to the mixture.

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EDITORIALS

SURGERY Gynecology and Obstetrics

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AUGUST 1944

WHAT KIND OF MEDICAL OFFICERS DO THE ARMED SERVICES WANT?

THE medical schools and civilian teaching hospitals of this country are engaged in the education of medical officers for the armed services. They are the only institutions in existence qualified to render this service and all of the physically fit males who go through this education will become medical officers in either the Army or the Navy. That the efforts of the medical schools and teaching hospitals have been successful is attested by the extravagant praise accorded especially to the surgeons in the Army and Navy for the astonishingly high percentage of wounded men returned to active duty. In a recent address before the American Surgical Association the Surgeon General of the United States stated that never before in any war had the wounded of our army received such excellent surgical care. Likewise many correspondents in popular articles have emphasized this fact. The influence of this

knowledge on the morale of both the combatants and the home front is incalculably great.

The surgeons who are responsible for this splendid record are men who not only had the benefit of four years in a medical school following a good premedical training in the colleges but in addition spent several years in special training in our civilian teaching hospitals. Many also have fulfilled the requirements for fellowship in the American College of Surgeons and for certification by the American Board of Surgery. They are the product of the resident plan of graduate instruction which required many years to become established on a sufficiently firm basis to influence appreciably the practice of surgery in this country. In the years immediately preceding the present war several hundred men annually were receiving a training which met the high standards of the American Board of Surgery. The army has recognized the importance of qualification by that Board and by the American College of Surgeons by giving a certain amount of preferential consideration to the members of the College and particularly to those who hold certificates of the American Board.

This splendid plan however which has been responsible for the excellent care of the wounded has been scrapped by the War and Navy Departments. Laymen who can have no adequate understanding of medical education have dictated what may be given in a premedical course and have practically destroyed the resident system of training. Many medical officers will now enter the army to serve in battalion aid stations and in other places demanding a knowledge of surgery

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whose maximum graduate hospital experience has been nine months of a rotating interne service with perhaps only two months in surgery. Is this the kind of medical officer the armed forces want? Pity the wounded if it is!

Let us imagine a group of surgeons with the authority to prescribe the education of line officers, be they army or navy. Would they wreck West Point and Annapolis. Would they reduce their faculties by 40 or 50 per cent at the same time that they increase the number of the students? Would they reduce the period of training of artillery officers or submarine commanders to an amount which could not possibly make them efficient? It seems unlikely that they would. Yet if they were to exercise an interference with the training of line officers analogous to what the War and Navy Departments have done to the West Points of medicine that is exactly what they would do.

Is the medical officer of less value than the line officer? The General Staff may think so but we know full well that a modern army could not function at all without its medical department. Conceivably it might dispense with any of its other branches temporarily but no large concentration of troops could occur anywhere without taking the steps necessary to prevent the spread of disease. That fact has been demonstrated so often in past history that no further argument in support of it is necessary.

Although the Surgeon General of the Army is no longer a member of the General Staff the army must appreciate the value of the medical officers because it wants so many of them even if they are only half baked. In fact much of the present difficulty arises because of the large number wanted. At the outbreak of the present war we were told that the army needed 6.5 medical officers for each 1000 men in the army. This formula was not in

existence during World War I but was arrived at later during peace time. Despite the excessively high ratio of one medical officer for every 154 men little harm would have resulted when considering a small peace time army. But what a difference when the General Staff began to talk in terms of an 8 million army and the navy of a force of two and one half millions! If the ratio were to be maintained, this meant that 68,250 medical officers were to be needed for the armed services out of a total number of approximately 160,000 medical graduates in this country. Only 58 per cent of those who had ever graduated from a medical school including those not in practice were to be left to care for the ill of the home population. Let us say that with 10 million of the population in the armed services the remainder would amount to 150 million. That would mean then one doctor for each 1293 people. In other words the civilian doctor would have 8 times as many people to care for as the army or navy doctor.

The demand for so large a number of medical officers is the fundamental cause of the disruption of the pre war efficient plan for their education. Apparently only numbers count because of the baneful influence of the magic ratio of 6.5 per 1000. "Better have a lot of poor medical officers than a smaller number of good ones" seems to be the philosophy of the laymen running the War and Navy Departments. We know the fallacy of that reasoning. Shall we send our men into battle with civil war muskets if the supply of modern arms is deficient? Of course not. Any body can see how ridiculous and murderous that would be. But perhaps only doctors themselves can appreciate how murderous a half-baked medical officer can be.

Is it necessary that this large number of medical officers be provided? If it is then everybody will be glad to make the best of it.

The armies of other countries have not been furnished with anything like so high a proportion of medical officers. The British the Australian and the Canadian armies for example get along with a proportion only a little more than one half of what is felt necessary by our armed forces and the quality of the work done is excellent. If all of the eight million men of our army were to be in combat at one time then one medical officer to each 124 men would not be an excessive ratio. But it is well known that only a small minority of the men in the army will ever participate in actual combat and all of that group will not be in combat at the same time. Is not this demand for so many medical officers an unjustifiable extravagance for which there is no demonstrated need?

These remarks have been directed at the evil effects upon the medical officers themselves caused by the disruption of the only plan for developing properly trained surgeons which has ever been found to work. A similar editorial could be written on the disaster to the civilian population. Are we to go back wards a quarter of a century and to surrender to our two great allies the enviable position in medicine which this country occupied before the war. The British Commonwealth and the United States have not found it necessary to disrupt

their medical education to anything like the extent which we have been forced to do. As a result we may find ourselves a poor third in medicine in the post war world. Is it necessary? I know of no convincing evidence that it is. But nothing will be done to remedy the situation unless the medical profession itself the only body capable of understanding how a medical officer should be educated speaks its mind loud enough for Congress and the President to hear. Reduce the 65 ratio to a reasonable one and much of the basis for the wrecking of our medical education will disappear. The 9-9-9 plan will not train surgeons and will not provide competent surgical officers. Still less will the nine months rotating internship. That plan should be scrapped and in its place a reasonable program for the training of medical officers should be substituted immediately after a proper inventory of the real needs of the armed services has been made.

Finally it is a pleasure to recall the wisdom of Aescop in this connection. The hen that laid a golden egg every day was killed by its owners in order to get all the gold at once. But alas! no gold was found inside its body and the source of the daily golden egg was destroyed. Is there not a parallel here?

ELBERT A. GRAHAM

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REVIEWS OF NEW BOOKS

IN the monograph of about 370 pages entitled *Iliter salpinger si* an exhaustive study of the subject of hysterosalpingography is presented. The opening chapters give a résumé of the history of the procedure and a description of the various methods which have been used. The relative values of the different opaque substances which have been employed, salts of thorium, bromide, and the various iodized solutions of water and oil are compared. Of the 450 cases which form the basis of this study 150 per cent either 25 or 50 per cent was employed in

The author in spite of his evident enthusiasm for this procedure, insists that roentgenology cannot be regarded as the only method needed and believes that an adequate history physical examination, and necessary laboratory work must not be omitted. The procedure should be carried out soon after the end of menstruation for sound physiological reasons which are given. In the great majority of cases the investigation was carried out upon ambulatory patients.

A chapter is devoted to accidents following the injection of opaque media. The sedimentation test, prior to examination, is recommended to avoid inflammatory reactions. Rupture of the tubes, iodism embolism abortion, the formation of oily tumors, the possible dispersion of malignant tumors, and the entrance of the oily substance into the veins of the uterus are all discussed.

In the chapter dealing with indications and contraindications, ten conditions are listed which may be studied. These may seem somewhat liberal to many gynecologists.

A chapter dealing with the normal appearance of the reproductive system upon roentgenologic examination is followed by one describing abnormal shadows. Both are accompanied by an adequate number of illustrations.

Chapters upon myoma and cancer portray the diagnosis of these conditions roentgenologically with illustrations supplementing the text adequately.

A number of authors are quoted who have injected opaque media into the pregnant uterus. In 2 cases attempted by the author of this work abortion followed promptly. Six cases of incomplete abortion were studied. These were all patients who had aborted some time previously and who had established irregularly since. While the diagnosis was needed to remove the product of conception, this might have been done at once serving the purpose

of diagnosis as well as treatment and thus avoiding the necessity of two attacks upon the interior of the uterus.

A discussion of the roentgenologic study of the cervix is given and an interesting chapter detailing the use of roentgenography in the study of sterility. This is one of the most important chapters in the book.

The author is quite definite in stating that, with good technique and proper precautions, danger is slight. The monograph closes with a list of conclusions and a bibliography containing 118 titles appended. The book is recommended to those who with a reading knowledge of Spanish, desire an exhaustive discussion of roentgenologic study of disorders of the female reproductive system. The conclusions may in general be approved.

W. C. DUFFY, M.D.

THE material presented in the book *Applied Dietetics* by Frances Stern has been assembled from the nutritional data compiled by Miss Stern and her associates at the Frances Stern Food Clinic, The Boston Dispensary. In the second edition, the latest developments and progress made in nutrition are brought up to date.

The author's long and varied experience with food her experience in the organization of the Nutrition Clinic, and in the teaching of many as for the writing of a book which presents a procedure for the planning and teaching of normal and therapeutic diets.

The method of teaching employed is based on the fundamental principles of nutrition food is made up of the same chemical elements as are found in the human body. When these foods are eaten, the body breaks them down by physiological processes that provide substances with which the body builds up and repairs tissues, provides energy, and regulates the various functions of the body.

The chapters on the construction of the normal and therapeutic diets are well presented. Starting with a discussion of the body's requirement of the different food constituents, the author then shows how the food prescription is determined on the basis of average height, weight, age, sex, and activity. The same principles that govern the normal food needs of the body are applied to the therapeutic diet. When the therapeutic diet is planned, a

HISTORICAL PTEROLOGY. By Edmundo Bortez Argente. Universidad Nacional de Córdoba, 1941. Córdoba, República

APPLIED DIETETICS: THE PLANNING OF THERAPEUTIC AND NUTRITIONAL DIETS. By Frances Stern. 2nd ed. Baltimore, Md. Williams & Wilkins Co. 1941.

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is made of the physiology and pathology of the part of the body affected. The normal diet is then modified in accordance with the diagnosis which has been established by the medical investigator.

A plan for a nutritional history is presented in detail. This history takes into consideration the many and various environmental factors that influence health and food habits. Emphasis is placed on the relation of food to personality. Importance of gaining the confidence of the patient is stressed, and suggestions are offered on how to gain this confidence and secure the interest and co-operation of the patient.

Approximately two-thirds of the information in this book is presented in tabular form. There are 57 co-ordinated tables that serve as references to simplify the computation of diets. The tables giving the vitamin content of the various food stuffs are of particular value. Other tables included are tables on the relation of food to the body constituents, food principal sources of the food constituents, food values and measures in terms of average servings of food (both in gram and household measures) and tables expressing the native background and food habits of some of the foreign born and their American adjustments. Complete dietary outlines and typical menus illustrate the dietary treatment of the various diseases.

This book should continue to be of value as reference material to the clinic dietitian, the medical student, and students of nutrition, nurses, social workers, public health workers, and teachers of nutrition.

PEARL LEWIS

THE recently published *Physical Foundations of Radiology* is a book that has long been needed by radiologists. Within this compact volume is a readable, practical explanation of physical principles used in every day radiologic practice. Information dealing with every physical phase of diagnostic and therapeutic roentgenology as well as with radium therapy is readily obtained from the orderly discussions. Included are interesting understandable descriptions of the modern cyclotron and its use in the production of radioactive phosphorus and other elements. A special appendix contains a ready source of dosage data for both radium and x ray therapy the well arranged complete dosage tables cover a wide range of variable treatment conditions.

For the resident or fellow in radiology there is embodied in this volume the essential knowledge of radiologic physics. Much of this material has been previously published by these authors and others in numerous individual manuscripts but never before collected in one unit. An excellent bibliography is included at the end of each chapter.

Since it is the orthopedist and general practitioner rather than the modern radiologist, who receives radiation injuries particularly from use of the fluoroscope the chapter on Protection should be read by these respective specialists. Hospitals or clinics planning installations of new therapy equipment have in this book a valuable aid in laying out their equipment most economically and safely.

A. F. GALLOWAY

PHYSICAL FOUNDATIONS OF RADIOLOGY By Dr. Chester, Ph.D. Edith H. Goss, Sc.D. Lecture 3 Taylor, Ph.D. and J. L. Wheeler was N.Y. New York Paul B. Hoeber Inc., 1944.

CLINICAL CONGRESS OF AMERICAN COLLEGE OF SURGEONS

W EDWARD GALLIE, Toronto *President*
IRVIN ABELL, Louisville *President Elect*

Committee on Arrangements

WARREN H. COLE *Chairman* MARSHALL DAVISON *Secretary*

PLANNING FOR A WARTIME CLINICAL CONGRESS IN CHICAGO

THE Board of Regents, at its meetings in Chicago on May 5 and June 17 approved the program that is being prepared for the 1944 Clinical Congress of the American College of Surgeons to be held in Chicago October 24-27. The general program will give consideration not only to the current and postwar problems of civilian surgical practice but will include a presentation of the latest developments of military surgery, so far as such information can be made available.

This will be the thirty-second session of the Clinical Congress heretofore held annually but interrupted in 1942 and 1943 by World War II. It is the eighth occasion since the first Clinical Congress in 1910 at which the surgeons of this great medical center have been privileged to act as hosts to so large a group of their colleagues. Over the years the annual Clinical Congress has become an increasingly important factor in the development of American surgery and due to the widespread interest already expressed the convenient location of Chicago with its exceptional transportation facilities and with ample accommodations for so important a meeting, a large attendance is anticipated.

Important features of the Congress include the Presidential Address and Convocation, with the inauguration of the new officers of the College, and the reception of the new officers of the College, Tuesday evening, October 24, a daily program of clinics in the medical schools and hospitals, evening scientific sessions, panel discussions, symposiums, the forum on fundamental surgical problems, conference on fractures and other traumas, special programs on ophthalmology and otorhinolaryngology, discussions of graduate training in surgery, the Hospital Standardization Conference, surgical motion picture programs, and the annual meeting of the governors and fellows.

THE CLINICAL PROGRAM

Under the leadership of a representative committee of Chicago surgeons a clinical program is being prepared to be presented at the medical schools, affiliated teaching hospitals, and other large hospitals, to include operative and non-operative clinics, demonstrations, and exhibits conducted by the surgeons and surgical specialists connected with these institutions. All the special fields of surgery will be represented therein, affording the visiting surgeons exceptional opportunities to study at first hand the latest advances in surgery as well as the important experimental and research activities of Chicago institutions. The program will present a wide variety of material in the fields of general surgery, fractures and other traumas, neurosurgery, thoracic surgery, orthopedic surgery, obstetrics and gynecology, ophthalmology and otorhinolaryngology. Clinics and demonstrations at the hospitals will be held on Tuesday afternoon, October 24, and on the mornings and afternoons of the three following days.

OPENING SESSION

The Congress will open at 9:30 on Tuesday morning with a general assembly in the ballroom of the Stevens Hotel. The President of the College, Dr. W. Edward Gallie of Toronto, will preside. Dr. Irvin Abell of Louisville, Chairman of the Board of Regents and President Elect, will preside on the field activities of the College since the last Clinical Congress held in Boston in 1941 and will summarize the accomplishments of a quarter of a century of hospital standardization. Reviews of the activities of the United States Army and Navy medical services in the war will be given by Norman T. Kirk and Vice Admiral Ross T. McIntire. "The Health of the Nation in Wartime" will be discussed by Dr. Thomas Parran, Surgeon

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General United States Public Health Service. Medical service in the Army Air Forces will be described by its chief surgeon Brigadier General David N W Grant. The Procurement and Assignment Services in the United States and in Canada will be described by respectively Dr Frank H Lahey of Boston Chairman of Direct Assignment Service, and Major General G B Chisholm D.S.O. M.C. Ottawa Director General of the Canadian Army Medical Service.

GENERAL PROGRAM

At the Presidential Meeting and Convocation on Tuesday evening in the Ballroom of the Stevens Hotel the new officers of the College will be inaugurated and initiates of the classes of 1943 and 1944 will be received into fellowship. Dr W Edward Gallie will deliver the presidential address at this session and distinguished visitors from foreign countries will be introduced. At scientific meetings on Wednesday Thursday and Friday evenings at headquarters eminent surgeons of the United States and Canada, and possibly visiting surgeons from foreign countries will present papers on surgical subjects of timely importance. The programs are in preparation under the direction of the Board of Regents and will be published in a later issue.

As it has been demonstrated at previous Congresses and sectional meetings that panel discussions afford an excellent medium for the exchange of information on selected topics programs for a series of these panels dealing with newer aspects of military and civilian surgery will be held during the Congress. Eminent surgeons will collaborate in the presentation of vitally important material and opportunity will be provided for the free discussion of the subjects from the floor by those attending the panels.

It is planned that the Forum on Fundamental Surgical Problems, which proved of great interest and value in Congresses held just prior to the war will again have its place in the program. The purpose of the forum is to enable younger men representing university departments of surgery to present the important results of their clinical and experimental work. While these activities have been somewhat reduced due to the war it is expected that a wide range of subjects will be included affording a most valuable insight into the latest work of many of the universities.

Both military and civilian surgeons of the United States and Canada and some visiting surgeons from abroad will participate in the demonstrations, panel discussions, and formal scientific

sessions on fractures and other traumas. Developments in the care of injuries suffered in civilian accidents as well as those encountered in military action, will be featured.

In recognition of the fact that cancer is a subject of increasing concern not only to physicians with the care of military patients but for those entrusted with the care of military personnel and veterans a symposium on this subject will be held in which will be covered as comprehensively as possible the developments in diagnosis and treatment since the last Clinical Congress in 1941.

A daily presentation at headquarters of a varied program of surgical motion pictures is planned to include the newest available films approved by the committee on medical motion pictures.

Meetings of the state and provincial judiciary, Credentials and Executive Committees will be held on Wednesday forenoon at headquarters with addresses by the President, officers of the College and the Regents. The annual meeting of the governors and fellows will be held in the Ballroom of the Stevens Hotel on Thursday afternoon beginning at 130.

OPHTHALMOLOGY OTORHINOLARYNGOLOGY

The general program of the Congress includes many features of special interest to those surgeons whose practice is limited to ophthalmology or otorhinolaryngology. In addition to operative clinics and demonstrations to be given daily at several of the hospitals, programs for a series of clinical conferences and scientific sessions to be held at headquarters are being prepared. Outstanding specialists will present papers of particular current interest and will lead the discussions. A series of selected motion pictures related to these special subjects will be exhibited.

FRACTURES AND OTHER TRAUMAS

Military medicine has focused considerable attention upon the treatment of fractures and other traumas, which coupled with experiences in civilian practice justify the devotion of several demonstrations, panel discussions, and formal scientific sessions to this special field. Both military and civilian personnel will participate. Developments in the care of injuries encountered in military action and those suffered in civilian accidents will be featured at the evening session on Wednesday which will include the annual oration on fractures and other traumas.

GRADUATE TRAINING IN SURGERY

The symposium on graduate training in surgery and the surgical specialties will provide a highly

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important feature of the Congress. It is scheduled to meet in two sections, one section to deal with the special problems of ophthalmology and otolaryngology, the other with problems related to the fields of general surgery and the surgical specialties.

Plans will be presented and discussed dealing with increased activity by the College in encouraging the inauguration or continuance by all qualified hospitals of the maximum number of opportunities for graduate training. These are necessary to meet the desires of physicians whose surgical training has been interrupted by military service and to compensate for unavoidable curtailment of educational programs during the war. Success in maintaining high standards of surgery after the war depends in large part upon the emphasis placed upon the proper preparation of the general surgeon and the surgical specialist.

HOSPITAL STANDARDIZATION CONFERENCE

Current problems of hospitals will be discussed at sessions constituting the Hospital Standardization Conference. The newer personnel policies, including speedier and more effective methods of training, will be discussed by authorities in personnel management. How labor and materials may be conserved through the use of labor-saving devices and the introduction of more efficient practices will be described. The relation to hospitals of the War Production Board, the War Relocation Commission, and other governmental agencies, in helping to solve the problems of shortages of supplies and personnel will be presented by representatives of various organizations.

Figuring prominently in the discussions will be government relationships with and aid to voluntary hospitals, with special consideration of developments in hospitalization aspects of the emergency maternity and infant care program, rehabilitation, distribution of penicillin, grants-in-aid and the obtaining of premises for needed expansion and modernization of physical plants. Post-war planning in all its phases will be featured throughout the conference.

The hospital sessions, beginning on Tuesday morning and continuing through Friday afternoon, will include general assemblies, panel discussions, round table conferences, consultation service, and demonstrations.

ADVANCE REGISTRATION

The hospitals of Chicago afford accommodations for a large number of visiting surgeons, but attendance at the Congress will be limited to a number that can be comfortably accommodated.

Surgeons who expect to attend the Congress will therefore register in advance. Admission to clinics at the hospitals and to certain scientific sessions at headquarters will be controlled by means of tickets issued to the visiting surgeons at the registration desk.

In accordance with a resolution adopted by the Board of Regents, fellows of the College whose dues are paid to December 31, 1943, initiates of the class of 1944, fellows and junior candidates in military service will not be required to pay a registration fee. For junior candidates not in military service the fee is \$5.00 for other surgeons is \$10.00.

HEADQUARTERS TECHNICAL EXHIBITION

Headquarters for the Congress will be established at the Stevens Hotel which affords unusual facilities for so large a meeting as the Congress. The grand ballroom and other public rooms on the second and third floors have been reserved for scientific sessions, conferences, and panel discussions. The Technical Exhibition, together with the registration desk, will be located in the large Exhibit Hall on the lower floor of the hotel where leading manufacturers of surgical instruments, sutures, dressings, pharmaceuticals, operating room equipment, x-ray apparatus and hospital equipment of all kinds, as well as publishers of medical books, will be represented in the exhibition.

CHICAGO HOTELS AND THEIR RATES

Chicago has many first-class hotels, several within walking distance of headquarters. Reservations for hotel accommodations should be made at the earliest possible date. The following hotels are recommended:

	Minimum rate each hotel	
	Single	Double
Atlantic, 516 S. Clark St.	\$2.50	\$3.50
Bismarck, 71 W. Randolph St.	3.75	5.00
Blackstone, Michigan Ave. at Balbo Ave.	4.00	5.00
Brentwood, 20 W. Madison St.	5.00	7.00
Chicagoan, 67 W. Madison St.	7.00	9.00
Decker, Walton Place at Michigan Ave.	4.00	4.40
Eastgate, 6 E. Ontario St.	7.00	7.00
Edgewater Beach, 5340 Sheridan Road	7.00	7.00
Harrison, 57 E. Harrison St.	4.40	4.40
Kickerbocker, 65 E. Walton Place	6.00	6.00
LaSalle, Madison and LaSalle Sts.	3.00	3.00
Madison Club, 505 N. Michigan St.	3.00	3.00
Merrison, 70 W. Madison St.	3.00	3.00
Palmer House, 5 E. Clark St.	7.00	7.00
Plattner, 9 N. Clark St.	5.00	5.00
St. Clair, 6 E. Ohio St.	5.00	5.00
Seneca, 200 E. Chestnut St.	3.00	3.00
Sherman, 66 W. Randolph St.	4.00	4.00
Stevens, 735 Michigan Ave.	7.00	7.00
	5.00	5.00

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FRACTURES OF THE CARPAL SCAPHOID IN THE CANADIAN ARMY

A Review and Commentary

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THE fractured carpal scaphoid presents one of the most difficult and unsatisfactory problems in traumatic surgery. The basis of this problem would seem to be the appreciation of the various pathological lesions and the application of the proper treatment to them. In this presentation we give the results of a study of 257 cases of fractured carpal scaphoids occurring in a period of approximately 3 years in the Canadian Army Overseas. The system of central filing of all medical documents pertaining to each soldier ensures accurate statistics on each of the cases and also accurate follow up in that recurrent complaints on any particular case if present would be encountered.

ANATOMY, MECHANICS OF FRACTURE AND THE HEALING PROCESS

The proximal row of carpal bones consists of the scaphoid, the lunate and the triquetrum. This proximal row has been well described as forming a segmented arch which is curved in two directions, convex on the radial and dorsal surfaces and concave on the volar and midcarpal surfaces.

From the No. 1 Canadian General Hospital, Canadian Army Overseas.

The scaphoid or navicular bone is the most lateral in the proximal row of carpal bones. It lies against the concave distal surface of the radius articulating with the radius above the lunate and capitate on its medial side and with the two multangulars on its distal surface. The internal structure of the scaphoid is cancellous in type. The features of its shape consist of a large gently concave medial surface for articulation with the head of the capitate or os magnum, a prominent tubercle on its volar and distal aspect to which are attached strong ligaments and a definite constriction about the center of the body or the waist of the bone. Its radial and proximal surfaces together form a convex surface the proximal three fifths being covered with cartilage for articulation with the radius, the distal two-fifths including the base of the tubercle being extra articular and providing attachment for ligaments. As mentioned before the distal and medial surfaces are articular. A narrow volar and a wider dorsal surface are described and both provide attachment for ligaments.

The ligamentous attachments to the scaphoid bear an important relation to the mechanics of fracture. First to be noted is that very

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strong and dense ligaments, spreading out in a fan like pattern secure the distal half of the scaphoid to the two multangulars and to the capitate bones of the distal row of the carpus. Similarly the proximal half of the bone has a very strong ligamentous attachment to the lunate. It will be realized that any strain placed on the midcarpal joint will also occur at the center or waist of the scaphoid bone.

Indeed the waist fracture of the scaphoid has been aptly called a continuation of the intercarpal joint line. Demonstration of these facts is clearly seen in the common type of fracture dislocation of the wrist,—the transscaphoid penicillinar dislocation. Here the intercarpal joint is disrupted the head of the capitate slipping dorsally off the lunate fracturing the scaphoid and carrying with it the distal fragment. The lunate retains its position and also its strong hold on its radial and dorsal surfaces. The tendon of flexor pollicis longus fits snugly against the scaphoid forming a sling or cradle for the bone.

The frequency of nonunion in the fractured scaphoid has attracted thorough investigation of the blood supply. The vessels of supply enter through two main areas, via the ligaments about the tubercle and those attached to the dorsal surface. Oblets and Halbschein, who examined 297 cadaver specimens reported that in 13 per cent there were no arteries at the waist or proximal to it, while in 67 per cent there were 2 or more foramina proximal to the midwaist. These figures illustrate the more proximal the fracture occurs, the more likelihood is there of disturbance of the circulation to the proximal fragment. With these figures one might say that fracture through the midwaist may interrupt the blood supply in one third of all cases.

Three types of fracture of the scaphoid are commonly described: fracture of the tubercle of the body and the fracture dislocation. Fracture through the body of the bone is further differentiated into waist fracture and proximal pole fracture. Differentiation of these latter two by definition is difficult and we feel unnecessary. For this report we have

classified as proximal pole fractures only those occurring in the upper third of the bone and which are obviously not waist fractures. Fractures occurring just proximal to the waist and which are dubious as to type we have included in the group of waist fractures.

The tubercle fracture is an avulsion fracture caused by forced extension of the wrist in ulnar deviation. The lateral condensation of the radiocarpal ligament remains intact and tears off its attachment to the scaphoid, i.e. the tubercle. This fracture is extra-articular and the blood supply to both fragments is always adequate.

The most common fracture is a transverse one through the body of the bone usually occurring at the waist, or the center of the body. However it may occur at any point in the proximal two-thirds of the bone. There are two points in the anatomy of the bone to favor fracture in the region of the waist. First, it is markedly constricted in this region and second multiple blood vessels commonly enter about the waist on the dorsal surface.

The key to the understanding of the simple waist fracture is the consideration of the scaphoid as being the link or stay between the capitate a bone of the distal row of the carpus and the lunate a bone of the proximal row. This theory has been recently re-emphasized (7). Any strain placed on the intercarpal joint will of necessity be transmitted to the waist of the scaphoid. When the wrist is not in forced dorsiflexion the relaxed ligaments prevent a concentration of force on any single bone (3). In a fall on the outstretched hand, however, which is the most common mechanism of injury the wrist joint is most commonly forced into hyperextension and radial deviation. In this position the scaphoid is fixed in the concavity of the articular surface of the radius. It will be realized that once the scaphoid is fixed, by pressure of the distal carpal any further movement at the intercarpal joint will tend to snap the scaphoid. Todd in 1921 very aptly called the common fracture of the scaphoid the snapped wrist type (10).

The variation in location of the fracture is dependent upon the amount of radial deviation of the wrist during the impact. With ex

DICKISON SHANNON FRACTURES OF THE CARPAL SCAPHOID

treme radial deviation about two-thirds of the scaphoid is fixed between the capitate and the radius and the fracture occurs in the region of the waist. With less deviation diminution in the amount of similarly fixed scaphoid occurs and the fracture occurs more proximally.

Bipartite scaphoids. In the early literature up to around 1930 there was considerable discussion in regard to whether a scaphoid in two parts was a fracture or a congenitally bipartite scaphoid. This question has now for some time been definitely settled. In this investigation only one case of bilateral congenitally bipartite scaphoids was found in checking the radiographic reports on nearly 1000 wrists.

The delaying effect of synovial fluid on the intra articular fracture. Todd remarked that delay in union and nonunion might be attributed to the fracture line being constantly bathed in synovial fluid. There was considerable discussion on this problem for some time. The solution was generally accepted to be in fractures of the scaphoid. He reported that no lytic action of synovial fluid was noted in his experiments and that any delay can be ascribed to the healing mechanism itself. Kellogg Speed reported that synovial fluid is actually nutritive rather than harmful. In recent literature there is no support to the theory that synovial fluid may be a factor in the delaying union.

The healing process. As stated Johnson's excellent experimental work on this problem has been generally accepted throughout the literature. He found that lack of all periosteal callus is one of the main factors in causing slower fusion of the fragments into a solid mass. He also noted in his experimental dogs that the zone of reaction in the fractured scaphoid is extremely small in comparison to that in the radius and extends only a few millimeters to each side of the fracture line.

STATISTICAL ANALYSIS

There were 257 cases in this series. The average age of patients in the whole group was 28 years. The average age of those with fresh fractures was 24 years. There were 124 fractures of the right side—49 per cent—and 133 of the left side—51 per cent. One hundred

ninety six, 75 per cent involved the waist, 23 or 15 per cent involved the proximal pole and 23 or 10 per cent involved the tubercle. Of the 196 waist fractures the diagnosis was made within 1 week in 125 cases within 1 to 5 weeks in 12 cases later than 2 months in 47 cases. Fracture dislocations occurred in 11 cases. Early complete excision was done in 1 case. Of the 38 proximal pole fractures diagnosis was made within 1 week in 12 cases within 1 to 5 weeks in 3 cases and later than 2 months in 23 cases.

There were 23 fractures of the tubercle.

The Fracture with Early Diagnosis

Of the simple fresh waist fractures or those treated within 1 week the average time before immobilization was 1.4 days. There were 116 cases without displacement of fragments and all united. Of 6 cases with displacement of fragments 2 united and 4 did not. The remainder of this group cannot be entered in the above classification because their roentgenograms were not obtainable for examination. From their histories it was gathered that in 1 case the scaphoid united while the other 2 resulted in nonunion.

The average period of immobilization in the 116 cases which united was 88 days or 12.5 weeks. Ten per cent were healed in 2 months, 48 per cent in 3 months, 74 per cent in 4 months, 82 per cent in 5 months, 91 per cent in 6 months and 100 per cent in 9 months. Twenty cases or 17 per cent of this group took more than 5 months to unite. An analysis of these cases showed that 12 of the 20 cases showed either a vascular necrosis or an unusual separation or angulation of the fragments.

Of the 12 cases of simple fresh proximal pole fractures those treated within 1 week 8 united and 4 did not.

The average period of immobilization for the 8 cases which united was 143 days (20 weeks).

Histories of 4 cases which did not unite follow.

CASE 90. Signa, S. aged 26 years. Roentgenogram shows a separation of 3 millimeters at the radial margin of the fracture line which was accepted. Wrist was kept in plaster for 6 months with

genogram showed proximal pole fracture—no displacement avascular necrosis of proximal fragment.

CASE 121 Cpl B aged 37 years. Diagnosis and recategorization to C-1 at 3 1/2 years following injury progressive weakness and pain since injury. Roentgenogram showed marked arthritis throughout carpus, cystic changes in fragments of scaphoid.

CASE 95 Pte W aged 33 years. Diagnosis at 13 months after injury sent to duty as disability was only slight returned 15 months later with marked disability subjectively and objectively discharged from the Army Category E. Roentgenogram showed displacement, cystic changes in fragments of scaphoid, sclerosis of fracture margins.

Four patients were discharged from the Army for other reasons than their wrist condition 3 of these were over 40 years of age when they reported their painful wrist and roentgenograms showed old ununited fractures with advanced arthritis of the carpus. Fourteen men of the group are carrying on full duties in the field.

In the group of cases with late diagnosis treated by immobilization there were 27 cases of which 6 united and 21 did not unite. In the ununited group 10 were recategorized.

Histories of the 6 cases that united follow

CASE 125 Pte B aged 24 years. Wrist fracture with no displacement diagnosis at 2 months united in 18 weeks.

CASE 159. Sgt B aged 30 years. Wrist fracture with no displacement diagnosis at 2 months united in 15 weeks.

CASE 20 Pte J aged 22 years. Proximal pole fracture with no displacement, diagnosis at 6 months, union in 15 weeks.

CASE 113 Pte H aged 25 years. Wrist fracture with no displacement, diagnosis at 6 months avascular necrosis of proximal fragment which is seen to be revascularizing definite progression to union not complete at 20 weeks.

CASE 70 1st B aged 20 years. Proximal pole fracture with no displacement, had immobilization for 6 months following original injury then off for 6 months at the end of which he reported again with a painful wrist, plaster reapplied for another 9 months with resultant union.

CASE 35 Pte B aged 22 years. Proximal pole fracture with diagnosis 9 months after injury kept in plaster for 9 months with resultant union.

For the study of the cases with late diagnoses treated by immobilization which did not unite refer to Table I

In the group of cases of ununited fractures treated by operation there were 30 cases (This figure includes 8 cases of early diagnosis

TABLE I.—20 LATE DIAGNOSED FRACTURES TREATED BY IMMOBILIZATION BUT DID NOT UNITE

Case No.	Time before diagnosis	History of persistent trouble over since original injury	Definite history of recent acute injury	Period of immobilization	Clinical result	Category assigned to	Follow-up period
98-97	3 yrs	Yes	N	4 wks	Poor	C	yr
30-2	No def. date	?	?	5 wks	Good	No	yr
107-4	5 mos	Yes	No	7 wks	Poor	C	yr
86-33	2 mos	Yes	N	8 wks	Poor	B-	yr
53-30	1 1/2 yrs	Yes	Yes	wks	Good	N	yr
4-23	3 mos.	No	Yes	wks	Good	N	1 1/2 yrs
43-76	1 1/2 yrs	No	Yes	wks	Good	N	mos
136-45	3 yrs	N	Yes	wks	Good	N	7 mos
00-27	3 yrs	Yes	N	13 wks	Poor	C	7 mos
50-30	mos	Yes	N	14 wks	Good	N	1 1/2 yrs
04-25	10 mos.	N	Yes	4 wks	Fair	C	yr
6-38	N def. date	N	Yes	20 wks	Fair	N	yr
73-28	N def. date	Yes	N	20 wks	Good	N	1 1/2 yrs
2-24	5 mos	Yes	No	20 wks	Good	N	mos
40-26	3 mos	?	?	20 wks	Good	N	yr
03-20	1 1/2 yrs	No	Yes	20 wks	Poor	E	
8-4	1 1/2 yrs	Yes	?	wks	Poor	E	
87-20	9 yrs	N	Yes	20 wks	Poor	E	
87-21	5 mos	?	?	3 wks	Poor	C	yr
73-20	6 mos.	?	?	20 wks	Poor	E	

215) In this group 21 grafting operations were done with 9 recategorizations 3 drilling operations with 1 recategorization 4 complete excisions all recategorized 1 partial excision and 1 open reduction. The last 2 were not recategorized.

In the *grafting operation* group of 21 cases 8 united with 1 recategorized and 13 did not unite and of these 8 were recategorized.

Of the 8 cases that united a graft was seen to be in good position in 6 cases. In the 2 other cases roentgenograms taken within 2 weeks of operation show no evidence of a graft crossing the fracture line.

Of the 13 cases that did not unite a graft was seen to be in good position in 6 cases was seen in very poor position in 2 cases and was not seen at all in 5 cases when there was still

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TABLE II—GRAFTING OPERATIONS

Case No.	Period between original injury and operation	Plaster before operation	X-ray arthritis	Appearance at time of operation				Graft in good position	Graft in poor position	Period of PFC after operation	Cast ed	No union	Category	Clinical result
				% Involved	Displacement	Location of P.F.	Local circulation							
66	none	No		?	?	?		Yes						
67	none	No		?	?	?		Yes						
68														
69	none	No wks	No	Yes	Yes	No	Yes	Yes				X	E	Poor
70	375	No	Yes	Yes	Yes	No	Yes	Yes				X	E	Poor
71	375	Yes	Yes	Yes	Yes	No	Yes	Yes				X	C	Poor
72	none	No	No	No	No	Yes	Yes	Yes						Graft repeated after 11
73	375	No	Yes	No	No	Yes	Yes	Yes						Good
74		No	Yes	No	No	Yes	Yes	Yes						
75	375	No	Yes	No	No	Yes	Yes	Yes						
76	375	No	Yes	No	No	Yes	Yes	Yes						
77	375	No	Yes	No	No	Yes	Yes	Yes						
78	375	No	Yes	No	No	Yes	Yes	Yes						
79	375	No	Yes	No	No	Yes	Yes	Yes						
80	375	No	Yes	No	No	Yes	Yes	Yes						
81	375	No	Yes	No	No	Yes	Yes	Yes						
82	375	No	Yes	No	No	Yes	Yes	Yes						
83	375	No	Yes	No	No	Yes	Yes	Yes						
84	375	No	Yes	No	No	Yes	Yes	Yes						
85	375	No	Yes	No	No	Yes	Yes	Yes						
86	375	No	Yes	No	No	Yes	Yes	Yes						
87	375	No	Yes	No	No	Yes	Yes	Yes						
88	375	No	Yes	No	No	Yes	Yes	Yes						
89	375	No	Yes	No	No	Yes	Yes	Yes						
90	375	No	Yes	No	No	Yes	Yes	Yes						
91	375	No	Yes	No	No	Yes	Yes	Yes						
92	375	No	Yes	No	No	Yes	Yes	Yes						
93	375	No	Yes	No	No	Yes	Yes	Yes						
94	375	No	Yes	No	No	Yes	Yes	Yes						
95	375	No	Yes	No	No	Yes	Yes	Yes						
96	375	No	Yes	No	No	Yes	Yes	Yes						
97	375	No	Yes	No	No	Yes	Yes	Yes						
98	375	No	Yes	No	No	Yes	Yes	Yes						
99	375	No	Yes	No	No	Yes	Yes	Yes						
100	375	No	Yes	No	No	Yes	Yes	Yes						
101	375	No	Yes	No	No	Yes	Yes	Yes						
102	375	No	Yes	No	No	Yes	Yes	Yes						
103	375	No	Yes	No	No	Yes	Yes	Yes						
104	375	No	Yes	No	No	Yes	Yes	Yes						
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106	375	No	Yes	No	No	Yes	Yes	Yes						
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111	375	No	Yes	No	No	Yes	Yes	Yes						
112	375	No	Yes	No	No	Yes	Yes	Yes						
113	375	No	Yes	No	No	Yes	Yes	Yes						
114	375	No	Yes	No	No	Yes	Yes	Yes						
115	375	No	Yes	No	No	Yes	Yes	Yes						
116	375	No	Yes	No	No	Yes	Yes	Yes						
117	375	No	Yes	No	No	Yes	Yes	Yes						
118	375	No	Yes	No	No	Yes	Yes	Yes						
119	375	No	Yes	No	No	Yes	Yes	Yes						
120	375	No	Yes	No	No	Yes	Yes	Yes						
121	375	No	Yes	No	No	Yes	Yes	Yes						
122	375	No	Yes	No	No	Yes	Yes	Yes						
123	375	No	Yes	No	No	Yes	Yes	Yes						
124	375	No	Yes	No	No	Yes	Yes	Yes						
125	375	No	Yes	No	No	Yes	Yes	Yes						
126	375	No	Yes	No	No	Yes	Yes	Yes						
127	375	No	Yes	No	No	Yes	Yes	Yes						
128	375	No	Yes	No	No	Yes	Yes	Yes						
129	375	No	Yes	No	No	Yes	Yes	Yes						
130	375	No	Yes	No	No	Yes	Yes	Yes						
131	375	No	Yes	No	No	Yes	Yes	Yes						
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140	375	No	Yes	No	No	Yes	Yes	Yes						
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148	375	No	Yes	No	No	Yes	Yes	Yes						
149	375	No	Yes	No	No	Yes	Yes	Yes						
150	375	No	Yes	No	No	Yes	Yes	Yes						
151	375	No	Yes	No	No	Yes	Yes	Yes						
152	375	No	Yes	No	No	Yes	Yes	Yes						
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157	375	No	Yes	No	No	Yes	Yes	Yes						
158	375	No	Yes	No	No	Yes	Yes	Yes						
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196	375	No	Yes	No	No	Yes	Yes	Yes						
197	375	No	Yes	No	No	Yes	Yes	Yes						
198	375	No	Yes	No	No	Yes	Yes	Yes						
199	375	No	Yes	No	No	Yes	Yes	Yes						
200	375	No	Yes	No	No	Yes	Yes	Yes						

no demonstrable progress to union. (Post operative times of these latter 5 roentgenograms 1 week 1 week 2 weeks 2 months 3 months.)

Established arthritis of the carpus was noticed in the preoperative roentgenograms in 4 cases in 3 the scaphoid did not unite

In 6 cases there was a recorded history of the patient's reason for admission being a fresh injury to an old fracture. In 3 of these cases the original injury was 5 years old and in 2 cases 1 year old. In none was union obtained and in only 2 cases was a trial period of immobilization given before operation.

There were 8 cases in which the preoperative roentgenograms showed definite sclerosis of the fracture margins. Two of these cases united.

There were 7 cases in which the preoperative roentgenograms showed definite displacement of fragments. Two of these fractures united.

For further study of the grafting operations refer to Table II.

In the *drilling operations* group there were 3 cases with 2 united.

CASE 130. Tpr T aged 23 years. In this case there is revascularization of a dead proximal fragment in a most excellent manner. A waist fracture of the scaphoid was immobilized for 8 months following injury at the end of which time a drilling operation was performed. Preoperative roentgenograms show that at this time the proximal fragment was one-third revascularized. Postoperative immobilization for a further 5 months did not cause any further revascularization but there did follow solid union with good clinical result.

CASE 33. Lieut. W. aged 30 years. Waist fracture of the scaphoid with slight displacement, immobilized for 6 months following injury at the end of which time a drilling operation was performed. Preoperative roentgenograms showed avascular necrosis of the proximal fragment and sclerosis of the fracture margins. Postoperative immobilization for a further 5 months resulted in x ray union and a good clinical result.

CASE 12. Pte. B. aged 38 years. Diagnosis and drilling 15 months after injury. Roentgenograms showed a displacement (minimal) and no sclerosis nor vascular changes. Postoperative immobilization for 10 months resulted in failure to unite and a markedly disabled wrist.

In the *complete excision* group there were 4 cases and all were recategorized. Two cases were fracture dislocations with poor reduction of the scaphoid fragments. The 2 other cases were diagnosed at 8 months and 3 months respectively and both were operated upon at time of diagnosis. All patients showed poor clinical results following operation and were recategorized.

In the *partial excision* group there was 1 case.

CASE 114. Pte. T. aged 21 years. This was a transscaphoid perisemilunar dislocation in which the fragments of the scaphoid were not properly reduced. The proximal fragment was excised after 10 weeks of immobilization. He was returned to full duties 5 weeks later with an excellent immediate result.

In 1 case *open reduction* was done.

CASE 144. Spr. R. aged 22 years. Diagnosis 5 months following injury. An open reduction operation was performed at this time. Roentgenograms taken 1 month following the operation show a marked displacement still present and no evidence of union. He was sent to full duties 3 months later and no further roentgenograms were obtained. He has not reported his wrist again in a period of 2 years.

Displacement

In the 125 cases of fracture with early diagnosis there were 8 displacements or 6 per cent. In the 70 cases of fracture with late diagnosis there were 36 displacements or 50 per cent.

In 6 of the 8 cases of fresh fracture with displacement the scaphoid did not unite.

In the fractures with late diagnosis 19 of the 24 recategorizations showed displacement of fragments.

Arthritis

In the group of cases with late diagnoses showing x ray evidence of established arthritis of the carpus at the time of diagnosis there were 18 or 30 per cent. Of these 7 were left alone without treatment their average age was 41 years and 1 was recategorized. An other 7 patients were treated by immobilization their average age was 31 years and 4 were recategorized. Four others were treated by operation their average age was 35 years and 2 were recategorized.

Avascular Necrosis

Avascular necrosis of the proximal fragment was seen in 7 of the cases with late diagnoses 10 per cent.

An exact figure of the occurrence of this complication in the fractures with early diagnosis cannot be given.

Sclerosis of Fracture Margins

Sclerosis of the fracture margins was seen in 16 of the series of cases with late diagnoses (ca. 25 per cent). In 11 of these cases the fracture was 1 year old or more when the diagnosis was made while in the other 5 cases the fracture was less than 6 months old.

That sclerosis of the fracture margins can occur within 4 months may be illustrated by this case.

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CASE 211. Lieut. D. aged 29 years. Waist fracture plaster applied on day of injury. A displacement was present which was not corrected, roentgenogram at 4 months shows the same displacement, no evidence of union, and definite sclerosis of the fracture margins.

Six of these underwent grafting operations, and 2 of these united. Three were treated by immobilization. In none was union obtained. All 3 were poor clinical results and were reamputated. Two patients left alone. aged 52 and 43 years, were discharged from the Army for other conditions, with their wrists being mentioned as moderately disabling. Five others left alone have been carrying on with full duties.

fracture of head of radius, 4 fracture of capitate 3 fracture of styloid radius 3 fracture of shaft of radius, 2 fracture of styloid ulna, 2 fracture of hamate 1 Bennett's fracture 1 dorsal dislocation of distal ulna, 1 fracture of humerus (supracondylar) 1 fracture of humerus (shaft) 1 fracture of clavicle 1 gunshot wound of hypotenar eminence 1

A list of the cases which required recategorization is given in Table III.

TABLE III.

Grade	Total	Fresh with displacement, union, etc.	Old and Fractured	Old with Displacement	Old without Displacement	Fracture Dislocation
B						
C-1						
C						
B	10				6	
Total	20				6	

ANALYSIS OF STUDY

We have presented a review of 357 cases of fractured carpal scaphoids. The results of treatment in those cases diagnosed early are quite satisfactory. In the main, but there are certain problems still presented by this group of cases which demand our earnest attention. In the cases not diagnosed early the results of treatment leave much to be desired. This is not a criticism of those handling the cases, but rather an indication of our faulty and confused knowledge of the essential problems of this particular fracture.

The results achieved in the treatment of the simple fresh waist fractures were excellent. Union occurred in all these cases. If such fractures are immediately immobilized and kept so for a sufficient length of time they will unite. The figures in this report and the impressions gathered from a review of the literature offer firm support to Boehler, Schneck, and Soto Hall, in the statement that by far the majority of fractures of the carpal scaphoid, if properly immobilized within a week will unite without undue delay and will cause

Cystic Changes

Local rarefaction. This process is interpreted as an extension of the local resorptive process at the fracture line. This extension takes a circular expanding form and shows on the roentgenogram as incomplete circular areas of rarefaction with their bases at the fracture line. In the cases with late diagnoses this picture in the roentgenograms could be discerned in about 40 per cent of cases. Cystic degeneration involving the whole of the distal fragment was seen in 3 cases.

The process of cystic change was not seen in the proximal fragment except locally at the site of fracture. It was seen with and without the definite picture of sclerosis of the fracture margins. It was seen at an early date (6 months after injury) and also at a late date (5 years after injury). Bone union was obtained in 5 cases of the 13 showing this condition.

Associated Injuries

It was noted that associated carpal injuries were extremely rare being present in only 5 per cent of all cases.

In reviewing the histories it was noted that the question of associated injuries had no relation to the union of the fractured scaphoid, except of course in the fracture dislocations to the same extremity are listed.

In the following tabulation the associated injuries to the same extremity are listed including the fracture dislocations which are recorded elsewhere. fracture of triquetrum, 6 in 5 cases an avulsion chip fracture off

no further concern. Boehler and Schnek both go so far as to say that one can expect 100 per cent union while Soto Hall states that over 90 per cent perfect results may be expected. In this series of 116 cases treated early and well all cases resulted in union. The problem does not lie in the treatment but rather in the diagnosis—indeed the major problems from fractured scaphoids arise from failure to make an early diagnosis.

A fractured scaphoid may be suspected from clinical examination but the diagnosis can be positively established or excluded only by roentgenograms. The latter must be taken in the anteroposterior, lateral and oblique positions. The oblique is the most important view and frequently several roentgenograms in the oblique position are necessary to bring the fracture line into view. It must be kept in mind that immediately after injury it is often difficult to establish the diagnosis roentgenographically. Only a very faint fracture line may be seen as in Figure 1. To overlook such a faint line is to court disaster as this case plainly shows. The same is true of the case in which a fracture is suspected from clinical examination but cannot be demonstrated by roentgenograms (Fig. 2). Such injuries must be treated as fractures until repeated roentgenograms in 2 to 3 weeks' time enable one to determine definitely whether or not there is a fracture present. Failure to take these pre-

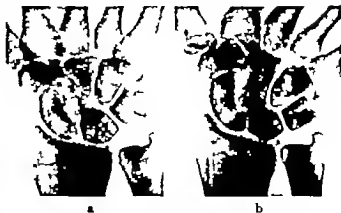


Fig. 1. Case 227. Pte. R., aged 22 years. a, Roentgenological appearance on the day of injury. There is a faint line in the proximal pole which was not noticed. A diagnosis of sprained wrist was made and the man was returned to duties. He came back 3 months later with persistent complaints about his wrist, and roentgenogram b was taken. A grafting operation at this time was unsuccessful. He was then under persistent medical treatment for 1½ years, at the end of which time he was discharged from the Army with the psychiatric diagnosis "reactive depression."

cautions will lead to the fracture being treated as a sprained wrist. In this series 18 of the 70 cases with late diagnoses were treated originally as sprained wrists. This is a very serious error and must be corrected. The diagnosis of sprained wrist should be made with the greatest of caution and only after fracture of the scaphoid has been positively excluded by repeated roentgenographic examinations.

In this series there are 125 simple waist fractures that were diagnosed early. In only



Fig. 2. Case 53. Gnr. L., aged 24 years. a, Roentgenogram taken on the day of injury which was considered negative for fracture. There is a faint but definite line through the waist of the bone. b, Roentgenological appearance 7 months later when he returned with the history of persistent complaints about his wrist. As the disability was not marked this patient was not told of his fracture and was returned to full duties. In a follow-up period of 5 months he has not reported his wrist again. c, Roent-

genogram, Case 104, Pte. P., aged 25 years, taken shortly after injury which was declared negative for fracture. There is noticeable a faint line at the radial side of the waist. The patient was returned to duties. d, the same case 8 months later when he returned complaining of persistent pain and weakness in his wrist. His wrist was immobilized for 3 months, at which time there was no demonstrable progress toward union and he was returned to duties with a lowered category.



Fig 3. Case
Lieut. H. Aged 20 years. a, Roentgenogram taken on day of injury showing displacement in the form of lateral deviation which, as not corrected, b, After 4 months of nonmobilization the roentgenogram was taken and showed the same displacement, the sclerosis of the fracture margins.—nonunion



Fig 4. Case
Gov. A. Aged 5 years. This wrist was immobilized in plaster the day after injury. The roentgenogram, as taken 3 months later and showed clearly displacement of the fragments in the form of angulation, with considerable separation at the radial margin of the fracture line. Nine months after injury at the time this report was made, he is still in plaster. This wrist also shows fracture of the ulnar styloid.

6 of these was there displacement and 4 of these developed nonunion. Displacement is a rare but serious complication and must be corrected. It may be a lateral deviation (Fig 3) a distraction of the fragments or an angulation (Fig 4) this last usually being a widening of the radial side of the fracture line. The wrist must be manipulated with a view to closing any gap that exists between the fragments and Soto Hall's description of a proper reduction and the means of attaining it can not be improved upon. Simply described this is dorsiflexion in radial deviation and impingement of the fragments by the greater multiangular using the thumb as a lever (Fig

5). Of course if there is marked irreducible displacement of a fragment or comminution with irreducible displacement, this is a different problem and is best handled by early operative removal of the displaced fragment or fragments before reactive hypertrophic changes are set up in the carpus.

When the proximal pole fractures which were diagnosed early are examined three points stand out. First there were only 12 of these as compared with 125 waist fractures. Second the average time required for union was 20 weeks, whereas in the waist fractures it was 12.5 weeks. Third, delayed union and nonunion occurred relatively much more often in this group than in the waist fractures. It has been pointed out that in fractures of the proximal pole vascular disturbances are more common than in fractures in other parts of the bone and frequently complete severance of the blood supply to the proximal fragment may occur leading to avascular necrosis of this portion of the bone. It is therefore to be expected that these fractures will take longer to unite than those of the waist. Nonplacement of the fragments is even more apparent when disarticulation of the fragments is present. Avascular necrosis is not necessarily a precursor of nonunion—it only delays union. Revascularization of the proximal fragment with



Fig 5. Gov. H. Aged 27 years. These two roentgenograms are taken while the patient is under general anesthesia and demonstrate clearly the effect upon the fracture of forced radial deviation, extension, and abduction of the thumb. a, Forced ulnar deviation; b, forced radial deviation.



Fig. 6. Case 30, Tpr T, aged 33 years. a, Roentgenogram taken 3 months after injury. The wrist was immobilized on the day of injury. Avascular necrosis of the proximal fragment is seen. b, 10 weeks later and after a total period of 24 weeks immobilization. The proximal fragment is seen to be about one third revascularized, and the fracture is uniting. Two months after this roentgenogram was taken a drilling operation was performed. c, Roentgenogram taken 5 months after drilling shows the fracture united. Following the drilling operation the proximal fragment did not revascularize any further. The patient's wrist had a total period of immobilization of 12 months. Clinically good result.

subsequent union of the fracture is clearly demonstrated by the case illustrated in Figure 6. But it should be noted that this took 12 months. From an examination of the cases in this group which did not unite it would seem that these points are not sufficiently appreciated. Displacement was not reduced and uninterrupted fixation was not persisted in until union was obtained.



Fig. 7. Case 83, Rinn B, aged 30 years. This roentgenogram was taken at the time of diagnosis, 8 years following injury. He had had a recent fresh injury which caused him to report. His wrist was now immobilized for 27 weeks at the end of which time he presented the picture of Sudeck's atrophy of the carpus, with marked disability, dependent cyanosis, advanced muscular atrophy, and marked limitation of all movements of the wrist. He was at this time discharged from the Army as unfit for any duties, on the basis of his wrist condition.

No matter how astute the medical profession may become in diagnosing fractured scaphoids early the late cases will always be present. Often the original symptoms are so mild that the patient pays little attention to them and it is not until months have passed with gradually increasing pain and disability that medical aid is sought. At times the original symptoms may entirely disappear and it is not until a second injury has caused symptoms that the patient seeks medical advice. In this report there are 70 such cases—cases



Fig. 8. Case 4, Gnr McL., aged 32 years. a, This roentgenogram was taken at the time of diagnosis showing an old fracture with established nonunion and advanced cystic changes in the distal fragment. His wrist was immobilized in an attempt to gain union. At the end of 10 weeks this treatment was discontinued and the patient was returned to duties. In a follow-up period of 1 year he has not reported his wrist again. b, The same wrist in plaster.

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Fig. 9. Case 3. Pte. M. aged 34 years. This roentgenogram was taken at the time of diagnosis, 6 months after injury. It shows no displacement and no sclerosis of fracture margins. His scapoid was grafted at this time, and with postoperative immobilization for 6 months the scapoid united soundly.

that were not diagnosed until at least 2 months after the injury. From a scrutiny of the Statistical Analysis of this group it is apparent that these cases gave rise to great difficulty in treatment that there was considerable variety in the methods of treatment and that the result of the treatment was frequently disappointing.

In this same analysis it is seen that the cases fall into three groups namely those who received no treatment those who were treated

by immobilization and those who were treated by operation. It must be pointed out that this division is not formed on a pathological basis but rather on varying idiosyncrasies of the surgeons who happened to be treating the cases. In one instance a patient would be returned to duty with or without his category being lowered depending upon the severity of the symptoms while in another instance a like case would be either immobilized or subjected to an operative procedure. From a study of this series it is impossible for us to say what is the best treatment in a given case but we are of the opinion that a careful examination of this group does lead to a better appreciation of the problems concerned in this type of case.

Twenty of the cases in this group with late diagnoses were not treated. In cases in which the symptoms were marked patients were re-categorized according to their disability and were sent back to duty. Fourteen of these 20 cases were able to return to full duties without recategorization. What the final result of this disposition of these 14 cases will be we cannot say. Up to the time this survey was made none of these patients had reported further trouble with their wrists. Whether a case of fractured scapoid can carry on indefinitely with no great disability we cannot say. It seems possible that a fracture without displacement or vascular changes might not give



Fig. 10. Case 75. Gnr. M. aged 43 years. a, Roentgenogram taken at the time of diagnosis, 6 years following injury. A grafting operation was performed at this time. b, Roentgenogram taken 8 days after the operation. There is marked increase in displacement of the fragments. c, Roentgenogram taken 8 weeks after operation, showing marked decalcification throughout the carpus except for the proximal fragment of the scapoid, which demonstrates

avascular necrosis. d, Immobilization after operation as to duties. He reported back 4 months later complaining of severe pain and disability and roentgenogram taken at this time. There is no evidence of union. His carpus has revascularized and the proximal fragment of the scapoid has revascularized there is radiological evidence of arthritis throughout the carpus.



Fig. 11. Case 95. Type B, aged 23 years. a and b Transscaphoid perilunate dislocation of the wrist, with associated fracture of the triquetrum. These two roentgenograms illustrate the relationship of the proximal fragment of the scaphoid with the semilunar and the distal fragment with the capitate, as discussed in the text.



Fig. 12. Case 78. Spr. F. aged 43 years. a and b Left and right wrists for comparison. This man injured his left wrist 13 years ago. He has noticed it to be somewhat weak at times, but it was never particularly troublesome. In the past few months, however, he has noticed steadily increasing pain and weakness, and he was sent to hospital for investigation. There was evident marked weakness of grip and about 50 per cent limitation of both flexion and extension of the wrist. He was considered unfit for any duties in the Army and was discharged on the basis of arthritis of the wrist.

rise to symptoms after the initial injury has subsided. In this series we have found several patients who have carried on for varying periods up to 15 years without any appreciable complaints and have reported only after they sustained a second injury to their wrist. On the other hand it seems reasonable to assume that if a wrist seen a few months after the fracture has occurred shows much displacement or vascular changes, ultimately arthritis will develop and the disability will be severe even though at the time first seen the symptoms may be quite mild.

Twenty-seven patients in this group with late diagnoses were treated by immobilization but in only 6 of these did union occur. The question immediately arises—why did the others not unite? This question can be answered only partially. It is unreasonable to expect that a fracture showing sclerosis of the margins would unite by merely being immobilized yet such fractures were treated in this way (Figs. 7 and 8). As pointed out in relation to the fresh fracture avascular necrosis delays union but does not cause nonunion and if such a fracture is treated by immobilization the treatment must be carried on without interruption until union is obtained even though this may mean a period of a year or more. Some writers claim that an old fractured scaphoid will unite if immobilized long enough provided there is not established nonunion. If this is true then some of these frac-

tures that did not unite were not immobilized for a sufficient period. We are unable to comment on this statement but it is interesting to note that no fracture united in which diagnosis was made later than 9 months after the injury and also that the fractures in which immobilization was persisted in for the longest periods without success gave the poorest results when treatment was discontinued (Table II).

The bone grafting operation was performed in 21 cases 2 patients having 2 grafting operations. Union was obtained in 8 cases. Examination of Table II shows that there is a great deal of confusion in the minds of the surgeons as to the purpose of the operation. Indeed in many of the cases one wonders why it was performed. In only 7 patients is there evidence of established nonunion—sclerosis of the fracture margins and union was obtained in only 2 of these. It is therefore in these 2 cases alone that one can credit the operation with having had a beneficial effect. In 7 cases of the group a period of immobilization with plaster was tried before operation but in 5 of these sclerosis was present. As pointed out it is useless to expect such treatment to have any effect. In any evaluation of results of operative procedures the postoperative period of immobilization must be carefully consid-

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ered (Fig 9). In the fractures that united following operation 14 weeks is the shortest period of immobilization while in those that did not unite their plaster was often removed in less than 14 weeks. The operation was performed on 4 cases with demonstrable arthritis of the carpus. One of these 4 united but the clinical result was poor and necessitated reoperation. Two of the 3 fractured operations resulted only in marked increase in the displacement of the fragments (Fig 10). There were two grafting operations in which the procedure incited the development of a vascular necrosis of the proximal fragment. In one of these cases revascularization occurred.

Classification of the indications for the use of this operation is imperative. There is only one proven indication for its use, and that is established nonunion—sclerosis of the fracture margins. So far as we can learn there is no reason to suppose that a bone graft will shorten the period required for a fractured scaphoid to unite and unless evidence of such is forthcoming the operation should never be performed for that purpose. The technical difficulties of the operation are great and it should be undertaken only after most serious consideration.

The drilling operation was done in 3 cases. Sclerosis was not present in any of these and avascular fragment was performed after evidence of revascularization. Five complete excisions were performed. In 1 case the scaphoid was excised within 2 weeks of injury for a displacement which could not be corrected. This man showed an excellent result in a follow-up of 6 months after his return to full duties. In the other 4 cases excision was done late and the results were uniformly poor. One excision of a proximal fragment done early gave a good result.

There were 11 cases of fracture dislocation in this series: 1 severe compound fracture dislocation, 7 typical transcarpal fracture dislocations, and 3 fractured scaphoids associated with a volar dislocation of the semilunar. In all these cases the proximal fragment of the scaphoid retained its relationship with the semilunar and the distal fragment with the capitate. This relationship is constant, and the reason for it has been pointed

out in the anatomical description of this report (Fig 11). These fractures are of course seen early and once the dislocation has been reduced the problem so far as the scaphoid is concerned is that of the simple fresh fracture. In summing up this study of 257 cases of fractured scaphoids, certain positive points stand out. These are not new—they have been pointed out by many writers before but surely they need re-emphasis. There are apparent however certain unsolved problems regarding this fracture to which we would draw attention.

The primary problem in this fracture is early diagnosis. With careful clinical and roentgenological examination repeated if necessary the diagnosis should not be missed. The fractured scaphoid diagnosed early and properly treated will almost invariably unite. If proper treatment is meant reduction of displacement if present, and uninterrupted immobilization with the wrist in extension and radial deviation until union occurs. Roentgenographic examinations must be made during the course of treatment. The plaster should be removed only for the few moments required to take the roentgenogram, and the surgeon should handle the wrist during this time to ensure that no disturbance of the fracture occurs.

Avascular necrosis may occur in the proximal fragment. This will delay union but will not necessarily cause nonunion. With uninterrupted immobilization revascularization will likely occur and union take place. Whether or not multiple drill holes will hasten the revascularization of such a fragment and thus shorten the period required for union we cannot say from the evidence of this study. In 1 case the drilling operation effected the cessation of revascularization of a proximal fragment when this was one third completed.

The fractured scaphoid diagnosed late is a very difficult problem. It is probably true that a fractured scaphoid never unites if left untreated. Will such a fracture if left ununited lead to a painful wrist in later life? We have shown that in some such cases patients carry on for long periods with only a minimum of discomfort. We have also shown that some are symptom free for a long

period and when injured a second time their symptoms are relieved by a short period of immobilization and that they are again able to carry on for considerable periods symptom free. But these are people in the third and fourth decades of life. What will happen to them in the fifth decade? That question we are unable to answer either from this study or from a perusal of the literature. That some of them develop marked disability in later life is undoubtedly true (Fig. 12) but if others may go through life with no significant disability then we must learn to select those that will not develop symptoms from those that will.

How to obtain union consistently in these late diagnosed fractures within a reasonable time is still an unsolved problem. Immobilization was often unsuccessful in the cases presented in this report. The criticism might be made that the immobilization was not carried on long enough. This may be true but we would point out the apparent danger of persisting in this form of treatment too long without evidence of progress toward union. Complete or partial excision is of no use in these fractures. Unless this operation is carried out soon after the fracture occurs the results will be uniformly poor. The drilling procedure may be of help in nonunion but we can form no opinion from this study. If non union becomes established union may be obtained by a grafting operation. This is however a difficult operation and a technique has

not yet been devised that offers reasonable hope of success.

The late fracture with degenerative arthritis is an arthritis problem and must be treated as such. Union of the fracture will not relieve the symptoms and palliative treatment is all that can be offered—fusion of the wrist being the last resort of the surgeon and warranted only by severe disability.

Finally, we would point out that the period required for healing in any fractured scaphoid may be very long. The patient may be able to carry on his occupation while undergoing treatment. Often however this is impossible in which case there is a serious economic loss. We have no suggestions for shortening this period but we would point it out as another problem facing all surgeons who treat this fracture.

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CALCIUM CHANGES IN ACUTE PANCREATIC NECROSIS

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THE predominant regional effects of acute pancreatic necrosis are dependent upon the action of damaging concentrations of escaped pancreatic enzymes. The purely chemical nature of tissue injury creates almost unique effects and fatty tissues to the gross chalky lesions occurring locally as a result of acute pancreatic necrosis. Eight years later R. Langerhans demonstrated that these lesions were the result of the reaction of lipase on neutral fat. He had identified pancreatic lipase and demonstrated its capacity to split neutral fat into fatty acids and glycerol. Fundamentally Langerhans showed that lesions of fat necrosis consisted of calcium soaps resulting from the enzymatic effect on neutral fats. He further showed that the glycerol by-product was absorbed without recognizable effect. Logical consideration of the quantitative factors involved would suggest that systemic effects might follow the dislocation of large amounts of calcium from the blood stream into the areas of fat necrosis.

The normal physiology of calcium balance in the body fluids is such that a normal total blood calcium is usually considered to vary from 9 to 11 milligrams per 100 cubic centimeters of blood although in a large series of adults Robertson found in a large series of 99 milligrams. Two roughly equal fractions of serum calcium exist. One half is combined with protein and constitutes the nondiffusible fraction. The combined calcium probably acts as a homeostatic reservoir contracting under conditions tending to deplete the diffusible calcium. However the amount of available combined calcium may be diminished due to plasma loss in shock states. Another reservoir

to maintain the diffusible calcium exists in the interstitial fluid and bone. The functional activity of this mechanism possibly is impaired in shock states.

The second half of the blood calcium is not combined and is in the diffusible state mostly ionized. This is the fraction which if reduced, produces physiologic effects and further it constitutes the source of calcium which is chemically available for combination with fatty acids in the formation of calcium soaps. In the normal adult of average weight the sum of these two fractions which is found in the total circulating blood is 650 to 700 milligrams of calcium.

The observation of a patient with fatal acute pancreatic necrosis in whom tetany existed with normal blood carbon dioxide combining power (33 E.) led to quantitative determinations of blood and tissue calciums which furnish the data upon which this report is based.

MATERIALS AND METHODS

For the investigation of the three phases of possible calcium disturbance mentioned in the previous discussion we have utilized a group of patients seen at the Los Angeles County Hospital between January 1940 and October 1943.

One group of observations consists of estimations of the total amount of calcium deposited in and around the pancreas in patients upon whom necropsy was done following death from acute pancreatic necrosis. In some cases an inaccurate antemortem diagnosis had been made and, therefore other calcium studies had not been done.

A second group of observations consists of measurements of the total blood calcium on patients with acute pancreatic necrosis and a third group consists of measurements of diffusible and nondiffusible calcium in patients who were known to have lowered total serum calcium.

Assisted by grants from the Michael J. Connel Fund.
From the Departments of Pathology and Surgery, School of Medicine, University of Southern California, and the Laboratory of the Los Angeles County Hospital.

The following procedures were used in making the determinations.¹ A number of check observations with an outside laboratory agreed with the findings as recorded.

Method for calcium on tissues. Five or 10 grams of the tissue are weighed out in a platinum or silica dish and dried at 120 degrees C overnight to remove most of the moisture. The samples are then ashed in a muffle at 500 to 600 degrees C until all the carbon is gone and only white ash remains.

After cooling the ash is dissolved in 3 to 5 cubic centimeters of tenth normal hydrochloric acid, heated to boiling and the solution filtered into a 30 cubic centimeter graduated centrifuge tube. Four extractions with hydrochloric acid are made filtering each successive portion into the centrifuge tube. Enough tenth normal hydrochloric acid is then added to each tube to make a volume of 15 or 20 cubic centimeters in order to have a constant volume for all samples. The hydrochloric acid is then neutralized with dilute ammonia to a pH of 5.0 nitrazine paper being used as an indicator. A blank made of 15 or 20 cubic centimeters of tenth normal hydrochloric acid and neutralized with dilute ammonia will give one a fairly accurate estimate of the amount of ammonia to use. The final volume is noted after neutralization. Saturated ammonium oxalate is added in the proportion of 1 cubic centimeter for every 5 cubic centimeters of solution present. The solution is allowed to stand 4 hours preferably over night.

It is centrifuged for 15 to 20 minutes at 3000 to 3500 revolutions per minute. The solution is decanted and allowed to drain for a few minutes. The sides of the tube and the precipitate are washed with 5 cubic centimeters of 2 per cent ammonia that has been saturated with calcium oxalate and then filtered. The tube is shaken thoroughly in order to break up the mat at the bottom. It is then centrifuged, decanted and washed again. After the second washing the precipitate is dissolved in an excess of fiftieth normal ceric ammonium sulfate—usually 10 cubic centimeters is sufficient. Two cubic centimeters normal sulfuric acid is added for each 10 cubic centimeters of ceric ammonium sulfate used. The tubes are

heated in a boiling water bath for 5 to 10 minutes until solution is complete. The solution is cooled and back titrated with fiftieth normal ferrous ammonium sulfate orthophenanthroline being used as an indicator. Two to 3 drops of a 0.025 molar solution is sufficient. The color changes from pale blue to red and the end point is very sharp. (Tenth normal solutions of the reagents named are prepared and diluted to fiftieth normal just before use.)

A blank determination is run. 10 cubic centimeters of fiftieth normal ceric ammonium sulfate, 2 cubic centimeters of normal sulfuric acid and 2 to 3 drops of orthophenanthroline and titrate with fiftieth normal ferrous ammonium sulfate being used. The calculation of the amount of calcium present is made as follows:

Blank—back titration of sample—Y or the number of c.c. of 0.02N ceric ammonium sulfate reacting with the calcium present.

1 c.c. of 0.02N ceric ammonium sulfate is equivalent to 0.4 mgm. calcium.

$$\frac{0.4 \times Y \times 100}{\text{grams of tissue in sample}} = \text{mgm. of calcium per 100 gm. of tissue (wet)}$$

Calcium determination—serum. Two cubic centimeters of serum are diluted with an equal volume of water and the calcium precipitated by 1 cubic centimeter of saturated ammonium oxalate. After complete precipitation the calcium oxalate is separated by centrifuging and is then washed twice with 2 per cent ammonium hydroxide—saturated with calcium oxalate.

The oxalate is then determined by oxidation with a slight excess of ceric sulfate. The excess being determined by back titration with ferrous sulfate. microchemical titration procedures being used. The procedure is essentially that which was described by Larson and Greenburg.²

Diffusible calcium. An ultrafiltrate of serum is prepared by means of a cellophane No. 300 film in a special filtering apparatus under about 50 pounds per square inch pressure. The ultrafiltrate is treated with ammonium oxalate and the calcium precipitated and determined in the same manner as serum calcium. By using smaller quantities of reagents

¹ Done with the assistance and supervision of Albert C. Chazoy, Ph.D.

² J. Biol. Chem. 138, 3, 99.

SURGERY GYNECOLOGY AND OBSTETRICS

6 The amount of diffusible serum calcium tends to remain stable in the presence of a decrease in total serum calcium

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SURGERY GYNECOLOGY AND OBSTETRICS

aseptic precautions. Wound repair was preceded by cleansing the skin thoroughly with soap and water followed by iodine alcohol and draping. The exit wound on the medial aspect of the thigh was first repaired. The débridement was complete in so far as all questionably devitalized tissue was completely excised. The skin edges were trimmed. The edematous subcutaneous tissue and the traumatized dusky red or purple discolored muscle were removed. All foreign bodies were removed. The wound was irrigated with saline solution and closed in layers with interrupted silk sutures and skin clips. The same procedure was used in closing the wounds of entrance except that the exposure of the injured nerve required an incision sufficiently long to reflect the lateral musculature of the thigh.

Repair of the nerve was carried out after complete débridement and irrigation of the wound had been accomplished. The bullet produced an irregular and ragged severance of the nerve and the nerve fascicles protruded from the epineurium and perineurium of the torn ends. The epineurium had usually retracted for a distance of 3 to 8 millimeters. Small blood clots were found around the epineurium and perineurium and the epineurium appeared swollen glossy and seemed to contain clear fluid. Ecchymosis discoloration

and edema affected both torn segments for a distance of 10 to 15 millimeters and the nerve showed a parallel striation which was perpendicular to its course and resembled muscle. Although the course of the bullet had been straight when piercing the thigh, the sheath canal was found not to be continuous between the muscles had changed their position at state of contracture. Thus the relation of nerve to muscles was changed which explained that frequently the contused or torn nerve was no longer in the area of muscle destruction. Nerve repair consisted of a local neurolysis trimming of the ragged nerve ends and end to end suture or implantation of a fresh homogenous graft depending on the amount of nerve destruction. The suture material used was fine black silk.

The gross appearance of the wounds surgically treated after 6 hours was indistinguishable from that immediately after injury except for an occasional edema. Wound after injury presented characteristic signs of infection the traumatized tissues became necrotic grossly edematous and developed an offensive odor. In several cases the entire thigh and leg were tumefied and grossly edematous. The most common organisms found (bacterial cultures taken just prior to

- Fig. 1. Immediate débridement of gunshot wound of the sciatic nerve.
- Fig. 2. Immediate débridement of gunshot wound of the sciatic nerve.
- Fig. 3. Débridement of gunshot wound of the sciatic nerve.
- Fig. 4. Débridement of gunshot wound 6 hours after injury.
- Fig. 5. Sixty days after immediate débridement and end-to-end suture.
- Fig. 6. Sixty days after débridement and end-to-end suture 6 hours after injury.
- Fig. 7. Sixty days after débridement and end-to-end suture 6 hours after injury.
- Fig. 8. Sixty days after débridement and end-to-end suture 8 hours after injury.
- Fig. 9. Sixty days after débridement and end-to-end suture 8 hours after injury.
- Fig. 10. Sixty days after débridement and end-to-end suture 24 hours after injury.
- Fig. 11. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 12. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 13. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 14. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 15. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 16. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 17. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 18. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 19. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 20. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 21. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
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- Fig. 97. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 98. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 99. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.
- Fig. 100. Sixty days after débridement and end-to-end suture 24 hours following gunshot injury in which sulfathiazole was used.



Fig. 1



Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9



Fig. 10



Fig. 11



Fig. 12



Fig. 13



Fig. 14



Fig. 15



Fig. 16



Fig. 17



Fig. 18



Fig. 19



Fig. 20

débridement) were *Bacillus coli* nonhemolytic streptococci, *Staphylococci albi*, *Bacillus proteus*, *Bacillus subtilis* and an occasional diplococcus.

In a series of animals various sulfonamide drugs were introduced locally into the wound at the time of débridement. The drugs used were powdered and crystalline sulfanilamide, powdered sulfathiazole and sulfadiazine. The drugs were distributed evenly in the entire wound before closure. One tenth gram (0.1 gm.) of drug was used per pound of animal weight giving an average of 0.7 gram in each wound. The implanted powdered drugs developed a paste like consistency especially around the nerve and were absorbed so slowly that 3 to 7 days were required before they had disappeared from the wound surfaces. Sulfanilamide was used in 37 animals, sulfathiazole in 35 animals and sulfadiazine in 24 animals while the wounds of 48 animals were not treated with any chemicals.

In 51 instances in which débridement was performed 24 hours or more after injury a sulfathiazole jelly was introduced into the bullet tract at the time the wound was received. This jelly is water soluble and contains sulfathiazole in a concentration of 5, 15, or 25 per cent. Three to 5 cubic centimeters of jelly was introduced into the depths of the wound from a metal tube through a fitted flexible metal conduit. These wounds were débrided in the same way as in the other animals and in 40 sulfonamides were powdered into the wounds before closure. The sulfathiazole level in the blood was determined at the time of débridement. The average level was 1.69 milligrams per cent after 24 hours and 0.33 milligrams per cent after 48 hours.

RESULTS

In spite of a careful débridement performed immediately after inflicting the gunshot wound the rate of infection and formation of extensive abscesses which burrowed along the course of the sciatic nerve and the fascial planes of the muscles was very high when the sulfonamides were not used in the wounds locally. The rate of massive infections increased the longer débridement was delayed. Thus in the series in which no sulfa drugs were

TABLE I.—THE RELATION BETWEEN THE INCIDENCE OF INFECTION AND LOCAL CHEMOTHERAPY IN GUNSHOT INJURIES

Time of debridement after injury	Local chemotherapy	Total number of animals	Percentage of infection in wounds		
			Untreated	Treated	
Immediate	None	34	38		
Immediate	Sulfonamides, and sulfathiazole jelly	40		5	
6 hours	None	7	4	0	
6 hours	Sulfonamides	20			
6 hours	None	3	33	3	
6 hours	Sulfonamides			5	
8 hours	None	8	62	5	
8 hours	Sulfonamides	8		27	7
14 hours	None	6	83	3	
14 hours	Sulfonamides	8		37	5
14 hours	Sulfathiazole jelly alone	8		5	
14 hours	Sulfathiazole jelly and sulfonamides			14	3
26 hours	Sulfathiazole jelly alone			00	
26 hours	Sulfathiazole jelly and sulfonamides	3		33	3
48 hours	Sulfathiazole jelly alone			50	
48 hours	Sulfathiazole jelly and sulfonamides	6		3	

implanted massive infections were encountered in 38.2 per cent of the 34 animals treated immediately after injury and in 42.9 per cent of the 7 animals operated upon 6 hours after injury. In the 11 animals débrided within 12 to 18 hours after injury massive infections developed in 54.5 per cent of them and this incidence grew to 83.3 per cent of the 6 animals treated after an interval of 24 hours. These infections usually became apparent 5 to 7 days after débridement repair and closure of the wounds and most of them developed rapidly into generalized septicemia and death, even though drainage was instituted as soon as the infection was noticed.

The local application of the sulfonamide drugs in the wounds at the time of débridement did not completely prevent the formation of infection. In this group of animals the rate of infection was also directly proportional to the period of time which had elapsed before the wounds were treated. The incidence of in

fibrous epineural proliferation with increased vascularization and predominantly lymphocytic foci but also a leukocytic infiltration which increased toward the suture line and over the distal segment. In the group II specimens (sulfanilamide) the same type of reaction but somewhat more marked was seen. In the group III specimens (sulfathiazole) there was very little cellular and fibrous proliferation over the central segment but the lymphocytic and histiocytic proliferation was more pronounced and there was a very marked vascularization of the distal segment. In group IV (sulfadiazine) a very marked cellular and fibrous proliferation with excessive vascularization was present over the central segment. These findings were still more marked over the distal segment combined with lymphocytic infiltrations with hemorrhages around the residual particles of sulfadiazine. Adhesions to the surrounding muscles were present in the group IV specimens (sulfadiazine) showing the granulation and mesodermal scar tissue infiltrating into the adherent scar.

The impression obtained from these observations is that the suture itself produces sufficient trauma to the nerve to cause a moderate epineural and perineural reaction which simulates the appearance of an inflammatory lesion. The use of sulfanilamide and sulfathiazole produced a more pronounced mesodermal reaction and sulfadiazine was followed by definitely stronger cellular and fibrous mesodermal reaction.

After 45 days group I specimens (no drugs) showed a slight fibrous proliferation with increased vascularization and scattered moderate lymphocytic infiltrations over the central segment.

After 60 days the group I specimens (no drugs) showed a moderate spongy fibrous epineural proliferation with very few lymphocytic foci but marked vascularization over the central as well as the distal segment. In the group II specimens (sulfanilamide) there was a moderate dense fibrous proliferation of the perineurium with increased vascularization and quite a few lymphocytic foci over both segments. In the group III specimens (sulfathiazole) a spongy fibrous proliferation of the epineurium with slight vascularization was present but there were few lymphocytic infiltrations in either the central or distal segments. In the group IV specimens (sulfadiazine) a fair amount of spongy fibrous proliferation with marked hyperemia, and no lymphocytic infiltrations was present over the central segment but there was an intense epineural proliferation over the distal segment.

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Fig. 2. Sixty days after end-to-end suture of surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 3. Sixty days after end-to-end suture of surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 4. Sixty days after end-to-end suture of surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 5. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 6. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 7. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 8. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 9. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 10. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 11. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 12. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 13. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 14. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 15. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 16. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 17. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 18. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 19. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 20. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 21. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 22. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 23. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 24. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 25. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 26. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 27. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.

Fig. 28. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfadiazine was used.

Fig. 29. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfanilamide was used.

Fig. 30. One hundred twenty days following the introduction of an autogenous graft in a surgically divided peripheral nerve in which sulfathiazole was used.



Fig. 21

Fig. 22

Fig. 23

Fig. 24



Fig. 25

Fig. 26

Fig. 27

Fig. 28



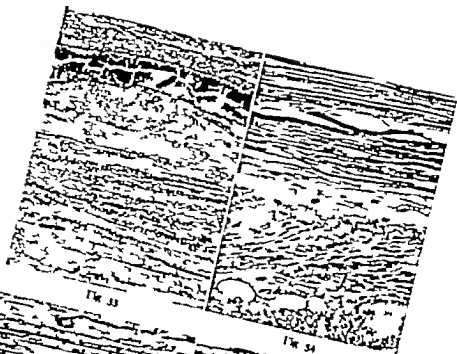
Fig. 29

Fig. 30

Fig. 31

Fig. 32

*Experimental Studies in Peripheral Nerve Surgery —
 Loyal Davis Frederick Hüller George Perret Walter Carroll*



Experimental Studies in Peripheral Nerve Surgery —
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The epineural proliferation apparently loses its chronic inflammatory appearance after 60 days in the central and distal segments and does not resemble that about the suture line. The comparison of the intensity of the epineural reaction of the 30, 45, and 60 day experiments showed a gradual decrease of epineural proliferation in the untreated sulfanilamide and sulfathiazole specimens whereas the sulfadiazine group revealed a persisting marked proliferative reaction throughout. The lymphocytic perineuritis which apparently was not a true inflammatory reaction was found in all experiments up to 45 days but had disappeared in the sulfadiazine group after 60 days. The animals treated with sulfanilamide showed moderate evidence of a true neuritis after 30 and 45 days. In general it may be said that sulfadiazine seems to provoke a stronger mesodermal reaction perhaps because of retarded absorption but it does not create the picture of a lasting chronic perineuritic inflammation.

A study of the specimens of end-to-end sutures performed under septic conditions showed that the regeneration of nerve fibers as well as axis cylinder formation, myelination and myelin decomposition organization presented no appreciable differences from these findings in the experiments performed aseptically. In general it may be said that the sulfonamide drugs protect the nerves from a

true neuritis or overcome this neuritis which was found to persist in 30, 45, and 60 day groups of the nontreated animals.

In the specimens of the aseptic as well as the septic experiments no evidence was found that the regeneration of nerve fibers axis cylinder formation the myelination or the absorption of myelin decomposition products was changed by the use of the sulfonamide drugs. It should be noted on the other hand that a strong mesodermal reaction which occurs around the site of the nerve suture leads to a deviation of regenerating nerve fibers into granulation and scar tissue to the degree to which the sutures. When mesodermal elements invade the surrounding muscles nerve fibers will often be seen growing with the mesodermal fibers into the perimysium of the muscle. Wherever the same kind of mesodermal proliferative reaction takes place on the surface of the central or distal segment a continuation of the mesodermal reaction at the suture sites again regenerating nerve fibers can be seen coursing within the epineurium of the central or distal segment. These deviating epineural nerve fibers over the central segment must be regarded as retrofanning out end of the central segment. This observation noted in a great number of specimens appears to be evidence against the gen-

Fig. 35. Aseptic end-to-end nerve suture, sulfathiazole—45 days. Photomicrograph of distal segment showing marked hyperemia, lymphocytic infiltration, edema, and a general cellular and fibrous proliferation of the perineurium. There are a few regenerating nerve fibers which can be identified in the epineurium. (Bodian fuchsin stain $\times 50$)

Fig. 34. Aseptic end-to-end nerve suture, sulfathiazole—30 days. The distal segment is in full regeneration, the endoneurial tubes are filled with myelin decomposition products, and a considerable number of gutter cells have accumulated around capillaries. The endoneurium reveals a two plus cellular proliferation and a rather uniform regeneration of nerve fibers following the endoneurium. (Bodian-fuchsin stain $\times 145$)

Fig. 33. Aseptic end-to-end nerve suture, sulfathiazole—45 days. Photomicrograph of the central segment showing undamaged axis cylinders and myelin sheaths without cellular proliferation, a somewhat thickened perineurium, and a proliferative epineurium with a strong vascularization. Schwann cells with regenerating nerve fibers passing between the mesodermal fibers are seen. This is a typical example of a retrograde perineurization in the central segment. (Bodian fuchsin stain $\times 225$)

Fig. 36. Aseptic end-to-end nerve suture, sulfadiazine—

45 days. This specimen shows a subperineurial edema seen commonly over the distal segment. The edema seems to be entirely inside the perineurium but does not penetrate to any measurable amount between the regenerating nerve fibers. It must be of some duration by virtue of the fact that quite a number of pyknotic nuclei and degenerating cells are seen within the edema. It is particularly interesting to see that the nerve fiber regeneration in the endoneurium is just as good close to the edema as far away. (Bodian fuchsin stain $\times 85$)

Fig. 37. Aseptic end-to-end nerve suture, sulfadiazine—45 days. The epineurium of the distal segment is in a state of lively cellular and fibrous proliferation. Between the proliferating mesodermal fibers chains of Schwann cells can be seen carrying regenerating nerve fibers. There is marked hyperemia and some cellular exudate. (Bodian fuchsin stain $\times 225$)

Fig. 38. Aseptic end-to-end nerve suture, sulfadiazine—30 days. A low power photomicrograph of the central segment showing a thickened perineurium, a highly proliferative vascular epineurium, and lymphocytic infiltration. There is a large number of regenerating nerve fibers which take their course from the suture line backward into the epineurium of the central segment. (Bodian fuchsin stain $\times 65$)

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crally accepted theory that the degenerating distal segment of a cut nerve exerts a kind of chemotropic influence on regenerating nerve fibers growing out of the end of the central segment. The truth of the matter is that of proliferating histiocytes, he it in the path of the degenerating nerve fibers. Further studies are being made to determine whether and to what extent a proliferation of Schwann's cells into the proliferating histiocytes is involved in this process.

The deviation and abnormal distribution of regenerating nerve fibers can be seen regardless of whether a strong mesodermal suture reaction or an epineurial reaction is traumatic infection or is caused by the irritation of the sulfonamide drugs. Extending as far as 1.5 centimeters in the epineurium of the central segment and almost a centimeter in the epineurium of the distal segment it is definitely more pronounced in the specimens in which the sulfonamide drugs were used. This fiber deviation is well developed after 30 days and later these fibers become myelinated.

In a series of experiments autogenous and homogenous grafts were used and the sulfonamide drugs were introduced into the wounds. To evaluate the effect of these drugs upon nerve regeneration through grafts, comparative studies have been made of the experimental material in control animals and those in which the drugs were used. All of the experiments hereafter described were performed under aseptic conditions and those analogous experiments conducted under septic conditions are not considered because addition of infection would complicate an interpretation of the effect of the drugs.

Central and distal sutures were made between the graft and the ends of the divided nerve. After 45, 60 and 75 days the area of the distal suture line was usually resected and resutured in accordance with an experimental

program to be reported upon later. The resected area, which represented the distal end of the graft, the line of suture and the entire nerve segment was studied microscopically and the entire specimen of nerve trunk and graft was removed for study after subsequent intervals of 45, 60 and 75 days.

Sixty days after the implantation of an autogenous graft the distal segment of nerve showed nerve fiber regeneration which varied between 1 plus and 2 plus. There was a beginning axis cylinder and myelin sheath formation which varied in degree in the different specimens but there was no difference between the specimens obtained in the nontreated and treated experiments. Studies of the entire specimen after a subsequent 60 day interval following resection and resuture at the distal suture line confirmed these findings.

A comparative study of the histological appearance of the area of the primary and secondary distal suture lines and the central suture line showed that the differences of the individual experiments within each group were more pronounced than the differences between the nontreated and the differences in the sulfonamide groups. The proliferation of the perineurium and epineurium in the graft varied between 2 and 3 plus with a slightly stronger reaction in the sulfonamide drug experiments. Adhesions to surrounding muscles were present in untreated and treated animals to an equal degree.

It appears that the irritation caused by the implantation of an autogenous graft varies between experiments and is not conspicuously affected by the use of the sulfonamide drugs. The appearance of regenerating nerve fibers in the perineurium and epineurium of the graft, which we believe depends upon the survival of endoneurial sheaths in the grafts, is not affected by the sulfonamide drugs.

Therefore, it may be said that experiments with autogenous nerve grafts under aseptic conditions show that the sulfonamide drugs do not interfere with the neurotization of the graft or the distal segment. Mesodermal proliferation at the area of the suture lines and in the grafts varies for one reason or another between experiments but there is no evidence

that the use of the sulfonamide drugs is a determining factor

The area of the central suture line in the homogenous graft specimens showed an equal mesodermal reaction in the nontreated and treated animals with the same individual variation between experiments in each group. The same was true of the areas about the primary and secondary distal suture lines. Nerve fiber regeneration axis cylinder and myelin sheath formation were equally prominent in the distal nerve segment of nontreated and treated animals. There was slightly more perineural and epineural proliferation in the homogenous grafts of the sulfonamide treated animals but the perineural neurotization was equally advanced.

One striking difference between the nontreated and treated animals in the homogenous graft series was that an heteromorphous neurotization of the graft was found in all of the sulfonamide treated animals whereas the grafts in the untreated animals showed in all instances at least some degree of isomorphous neurotization. This may be explained by a more intense and irregular endoneural mesodermal reaction initiated by the sulfonamide drugs in homogenous grafts in which are found large areas of necrosis which destroy the original endoneural structure and lead to a heteromorphous mesodermal infiltration from without.

It may be said therefore that the neurotization of the distal segment in homogenous grafts is not altered by the introduction of the sulfonamide drugs. More so than in the autogenous grafts it appears that the mesodermal reaction of the perineurium and epineurium of the homogenous graft is more marked under the influence of the sulfonamide drugs.

SUMMARY

The use of the sulfonamide compounds in experimental wounds produced an increased amount of adhesions which fixed the nerve to the surrounding tissue. These adhesions were thicker and more extensive about the grafts particularly the homogenous grafts. The use of the sulfonamide drugs was accompanied by an increased mesodermal proliferation at the suture line and at the same time led to a more intense neurotization of the scar tissue in the suture line. This was in addition to the moderate epineural and perineural reaction produced by the trauma of the suture. In general it may be said that sulfadiazine provoked the most marked mesodermal reaction perhaps because of retarded absorption although the findings were in no instance those of a lasting chronic perineuritic inflammation.

No conclusive evidence was found that the regeneration of nerve fibers axis cylinder formation myelination or the absorption of myelin decomposition products was changed by the use of the sulfonamide drugs. The deviation and abnormal distribution of regenerating nerve fibers were observed regardless of whether a strong mesodermal suture reaction or an epineural reaction was traumatic infectious or was caused by the irritation of the sulfonamide drugs.

The sulfonamide drugs did not interfere with the neurotization of an autogenous or homogenous graft or the distal segment. However in the homogenous graft series a heteromorphous neurotization of the graft was found in all of the sulfonamide treated animals whereas similar grafts in untreated animals showed in all instances some degree of isomorphous neurotization.

PERILUNAR DISLOCATION OF THE CARPAL BONES AND DISLOCATION OF THE LUNATE BONE

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THE numerous contributions to medical literature during the past 15 years on dislocations that concern the lunate bone are proof of continued interest in this field. Recurrent discussion has been provoked for the most part by two factors. In the first place the surgeon feels concern that these injuries are seen too often in the late stage when conservative treatment is useless and when even skillful operative interference may be followed by serious functional changes in the wrist and hand. Either the lesion continues to develop or the final result is misinterpreted in the early stage. Second because of the diversity of opinion as to whether operative reduction or extension of the lunate bone is the better treatment when conservative measures fail or when the location is of long standing surgeons have been stimulated to record their experiences and to try to arrive at some reliable conclusions. Still another impetus to discussion of these luxations has been the need of clarification of the conception of dislocations involving the lunate bone. This aspect of the lesion has been considered by foreign writers far more than by English contributors.

The purpose of the writer in adding to the literature on this subject is three fold (1) to emphasize again the importance of early diagnosis and treatment (2) to describe in simple form the dislocations that concern the lunate bone and (3) to present the observations and results in a series of 24 cases.

TYPES OF DISLOCATION

Research of this subject reveals that dislocations involving the lunate bone are designated by as many as 10 different terms. Thus the lesions are referred to as dislocations of the lunate bone, dislocations of the carpus, subtotal retrolunar subluxation of the carpus, backward displacement of the os magnum or

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perilunar luxations of the carpus. Not only is such extensive terminology confusing but a clear picture of the types of dislocations is seldom presented. Most writers have in fact, grouped all dislocations under the term *dislocations of the semilunar or lunate bone* whereas this bone may be in practically normal position with the carpal bones dislocated around it. Other writers prefer the use of the term 'perilunar luxation of the carpus, and include under it actual displacements of the lunate bone.

It would seem necessary to recognize a typical dislocations involving the lunate bone a simple classification that is based upon the special joint relations existing at the time of examination. The first type is the perilunar dislocation of the carpus in which the distal row of carpal bones is displaced around the lunate bone while the latter retains its normal or practically normal relationship with the radius (Fig. 1). The dislocation is usually backward and upward and may be complicated by a fracture of the navicular bone or of a styloid process although a perilunar dislocation toward the volar aspect is not unknown (Fig. 2). The second type is a dislocation of the lunate bone itself usually volar (Fig. 3).

Observers who have been particularly interested in the mechanism of these injuries claim that all dislocations involving the lunate bone are of the perilunar type at the start, and that the dislocation of the lunate itself is a secondary stage of a luxation of the carpal bones.

This may be true but the fact that the lunate actually dislocates losing its relation with the radius, and that under such circumstances treatment different from that of the perilunar luxation is called for makes it necessary to consider the secondary dislocation as a separate entity regardless of the theories of mechanism.



Fig. 1. A. P. A fresh dorsal perilunar dislocation of the carpal bones complicated by fractures of the navicular bone and the ulnar styloid process.



Fig. 2. H. S. a, left, A fresh volar perilunar dislocation of the carpal bones. b, Reduction obtained by the manipulative method.

The lunate bone when dislocated volarward may be found to have pivoted on the intact volar radiocarpal ligament so that it lies rotated from 90 to 270 degrees (Fig. 4). Usually the bone is found rotated about 90 degrees. In severe cases in which the volar radiocarpal ligament also is ruptured the lunate may lie entirely free in the soft tissue in front of the forearm bones.

Both types of dislocation but more often the perilunar may be associated with other carpal injuries in particular with a fracture of the navicular bone and less often with a fracture of the radial or ulnar styloid process. The navicular is fractured transversely through the midline and the proximal fragment remains in contact with the lunate bone displacing with it or retaining its relation to the radius according to the type of lesion whereas the distal fragment is displaced with the carpal bones. In 11 of the 24 cases being reported (1 bilateral case) there was an associated fracture of the navicular either alone or in combination with fractures of the styloid processes and in 5 cases the styloid processes were fractured.

MECHANISM

The generally accepted theory of the mechanism of both perilunar luxations and dislocations of the lunate is as follows. A person in



Fig. 3. C. H. a, left, A fresh volar dislocation of the lunate bone. Note the rotation of the lunate and loss of normal relationship with the radius. b, Roentgenogram following manipulative reduction.

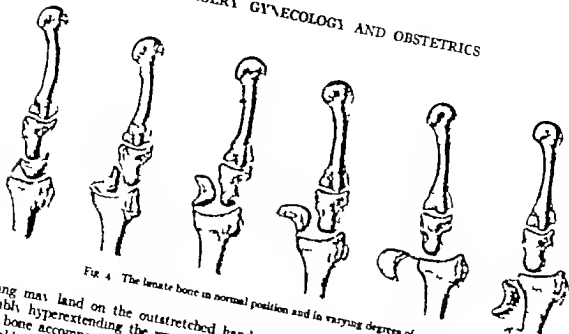


Fig. 4 The lunate bone in normal position and in varying degrees of rotation.

falling may land on the outstretched hand forcibly hyperextending the wrist. The capitate bone accompanied by the distal row of carpal bones rides upward and backward. The volar ligaments between the lunate and the capitate are torn but the volar and dorsal ligaments between the radius and the lunate remain sufficiently intact so that the lunate maintains practically normal contact with the radial surface. The dorsal surface of the lunate may displace slightly forward but no true rotation of the bone takes place owing to the intact dorsal ligament and capsule. Thus the perilunar type of dislocation is produced.

When the capitate in its backward course is forced against the radial margin the lunate bone under the pressure may be squeezed forward out of its socket. This may happen at the time of the original injury or secondary to a perilunar dislocation. In such cases the dorsal radiocarpal ligament attached to the surface of the lunate is torn. The lunate then proceeds to rotate forward and upward on the intact volar radiocarpal ligament. Eventually the head of the capitate may come to articulate with the radius (Fig. 4).

In the usual dorsal dislocation of the lunate bone the mechanism is the reverse of that in volar dislocations. The injury is one of forcible hyperflexion of the hand in which the capitate and distal carpal bones displace volarward around the lunate bone. The volar

radiocarpal ligament connecting the radius and the lunate gives way, and the lunate is squeezed out of position and rotates upward on the intact dorsal radiocarpal ligament.

Observers who have been interested in explaining the origin of these lesions have questioned the origin of these lesions have the form of anatomical irregularities and variations. Etienne pointed out that the facets of the lunate bone may be irregular in robust subjects and it is this type of person who is often exposed to the injury in his work. Delbet (quoted by Rauber '30) gave importance to certain ligamentous variations as favoring dislocation. Schnek considered the exaggerated obliquity of the distal radial articular surface of importance in the genesis. Certain of these variations have been found in cases of dislocation but also some lesions do not have such irregularities.

OCCURRENCE

These dislocations although among the more common carpal injuries are not of frequent occurrence and the general practitioner is likely to see a case only occasionally. Rauber ('30) called attention to the small number of 8 such dislocations that were found among 11,650 accidents. Mahorner and Meade noted only 3 cases among 649 fractures that had been treated at a male fracture clinic over a period of 2 years. Over a period of 27 years only 24 cases have come to my attention.

CLINICAL FEATURES AND DIAGNOSIS

The importance of immediate recognition of these dislocations cannot be overemphasized. In the short period of time immediately following the injury, that is, to the limit of 2 weeks, reduction can usually be accomplished by conservative measures, whereas later reduction even by operative intervention might be too traumatic to be feasible. Should the injury go untreated or the treatment be inadequate, the function of the hand and wrist is likely to be permanently impaired through the damage to the soft structures and tendons.

Definite clinical and radiographic features are characteristic of these injuries. The patient usually gives the history of a fall on the outstretched hand. In fresh volar dislocation of the lunate bone there is an alteration in the contour of the anterior surface of the wrist where in place of the usual concavity are found a prominence and thickening of the tissue. Quite typical is the position of slight flexion in which the majority of patients hold the fingers. Due to the locking by the displaced lunate bone the motion of the wrist is limited in flexion and the fingers cannot be fully extended. An important clinical feature is any evidence of irritation or damage of the median nerve from pressure of the dislocated bone; this may be in the form of a tingling sensation, paresthesia, or even excruciating pain.

The identification of the dislocated lunate bone on the palmar surface of the wrist under the flexor tendons is relatively easy by palpation and the area is tender to pressure. On the dorsum of the wrist at the normal site of the lunate bone is a depressed area that admits the finger tip and is tender. If there is also fracture of the navicular bone, pressure in the anatomical snuff box elicits tenderness.

A fresh perilunar dislocation of the carpal bones upward and backward is characterized by a prominent ridge running across the dorsum of the hand below the wrist joint. There is some swelling in this region, a deformation at the wrist joint may be noted, and if the infiltration is not too great it may be possible to palpate the edge of the capitate bone on the dorsal surface of the wrist. It is not possible to palpate the lunate bone which remains in

normal relationship with the radius. Motion of the wrist and fingers is limited and painful. In volar perilunar dislocations the prominent ridge is found on the palmar surface of the wrist and the distal edge of the lunate may be palpated on the dorsal surface.

The ultimate and detailed diagnosis of any of these dislocations rests with the roentgenogram. A true lateral view should be obtained to demonstrate the dislocated lunate bone or carpal bones and anteroposterior views are needed to reveal any associated fractures. Stereoscopic studies give the most accurate picture of these injuries.

TREATMENT

Conservative Treatment. There is now general agreement that immediate manipulative reduction is the treatment of choice in fresh dislocations. A fresh dislocation is considered one that is less than 2 weeks old. If reduction can be accomplished within this period the procedure gives almost constant success.

Manipulative reduction of fresh dorsal perilunar dislocations. General anesthesia is used. The operator grips the patient's forearm between his own forearm and chest, placing his thumb against the displaced capitate bone. With his other hand the operator then grasps the patient's hand and increases the deformity while applying traction at the same time. The next step is to press with the thumb against the os capitate with the traction still applied and force the hand first into extension and then into flexion. The procedure is not unlike that used in the reduction of a Colles' fracture. The reduction is checked immediately by roentgenograms. The wrist is then immobilized in an anterior plaster shell extending from the knuckles to the elbow in the position of flexion of from 30 to 40 degrees.

Fixation is maintained for 3 weeks in cases in which there are no associated fractures. Exercises and use of the fingers are begun as soon as the operative discomfort has subsided. After 3 weeks the wrist is brought to the neutral position and thus maintained for 2 weeks longer. Still another week of fixation with the wrist in the position of slight hyperextension is advisable. In the later convalescence an adhesive strapping a leather wrist

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let or a bandage provides sufficient protection but for a complete in 6 weeks or a month as would be necessary in playing golf should be avoided for at least 3 months.

Manipulative reduction of fresh ulnar dislocations of the lunate bone. General anesthesia is used. The operator grips the patient's forearm between his own forearm and chest placing his thumb over the dislocated bone. With his other hand the operator applies traction on the patient's wrist and dorsiflexes it. As the pocket for the lunate is opened up the operator pushes the bone into place by further countertraction seems to be necessary. It may be provided by an assistant. Then the traction is still continued the operator forcibly flexes the hand and upon this maneuver the lunate is felt to snap into place. If reduction has been obtained the hand will remain in the flexed position if reduction has failed, the hand will spring back voluntarily into the position of extension. In the latter event a second attempt at reduction may be made under fluoroscopic control provided that no undue traumatizing force would be required to replace the lunate. Roentgenograms should be taken to check the reduction. The after-care follows along the same lines as that of perilunar dislocations.

Alternate methods of manipulative reduction. The so-called broom-handle method of reducing a dislocated lunate bone has been recommended by a few operators (22). It consists of forcing the lunate into place by rolling a piece of a broom-handle over the anterior surface of the wrist while the hand is being hyperextended under traction. This method is not generally recommended as it involves the danger of damaging the soft structures and it exerts a less direct force on the lunate than the traction method of reduction in both the perilunar dislocation and dislocation of the lunate has given good results in the hands of some operators (1, 9, 17). This method consists of applying strong longitudinal traction on the outstretched fingers for a period of at least 10 minutes. If the lunate bone is displaced, this pull opens up the space to receive it and the pressure of the flexor

tendons forces the bone back into place. Following the reduction of the lunate bone the wrist is immobilized in the neutral position. Following the reduction of a perilunar dislocation the wrist is immobilized in the position of flexion and slight deviation to the ulnar side.

Operative treatment. The time limit for successful manipulative reduction is found to vary with the operator. Some surgeons are opposed to manipulative attempts later than 4 or 5 days after the injury. Most operators place a limit of 2 weeks on manipulative treatment believing that after this period the force necessary to effect reduction would be too traumatic. Once fixation has taken place the repair process sets in rapidly. Ligaments contract tissue becomes organized and adhesions stabilize the bones in malposition. The space normally occupied by the lunate bone becomes filled with organized blood clot and fibrous tissue.

Followers of the Boehler traction method recommend attempting closed reduction as late as 3 weeks after the injury. In such cases the traction is prolonged and even skeletal traction may be used. The advisability of using traction in dislocations of long standing is to be questioned. The pull must be strong and prolonged in order to overcome scarred tissue and there is the danger of further damage to torn ligaments and capsule.

Operative treatment of dorsal perilunar dislocations. Operative indications are recognized under the following circumstances. A fresh dislocation that is associated with a great deal of damage to the joint structures or to the median nerve is best treated operatively since attempts at manipulative reduction would cause further trauma. Fresh perilunar dislocations that cannot be reduced by manipulation are treated operatively. Open intervention is indicated in cases of more than 2 weeks standing.

The same dorsal approach is used as in reducing dislocations of the lunate bone (described later). New tissue formation is removed from about the lunate bone. The carpal bones are brought into position by placing a blunt director on each side of the scaphate and using the lunate bone as a point

of leverage. The posterior ligamentous structures are repaired when possible in order to stabilize the reduction. When the dislocation is of long standing that is from 6 to 8 weeks or longer it may be advisable to apply traction for a few days before the reduction in order to overcome the contraction of the tissues and muscles and to pull the carpal bones slightly downward. Following reduction the hand is immobilized in the position of flexion and the after-care is carried out along the same lines as that of manipulative treatment of perilunar dislocations.

Perilunar dislocations in elderly patients with arthritic joints when complicated by excessive damage to the tissue structures and a disturbance of the circulation are best treated by arthrodesis of the lunate, navicular and capitate bones. Under such treatment the patient recovers a hand that is fitted for ordinary use and work, whereas following reduction of the dislocation the wrist is likely to be painful and limited in motion.

Operative treatment of volar dislocations of the lunate bone. Operative intervention in the writer's opinion is indicated in the event of the failure of manipulative reduction or in cases that are seen more than 2 weeks after the injury. Should operative intervention consist of reduction or of excision of the bone? For years there have been two schools of opinion on this question. In the past excision has tended to be the procedure of choice probably for two reasons. Excision is a far less complicated procedure than replacement of the bone. There was also the alleged belief that malacia or necrosis of the lunate bone eventually follows operative reposition. More recently reports of successful surgical replacements have led to a revision of opinion in favor of operative reduction. In selected cases (1, 2, 5, 6, 10, 11, 14-16, 18, 19, 20) although there is still a small group of operators who regard excision as the accepted method because of the danger of the development of arthritis from the traumatic dissection required in operative replacement (4, 8).

As to the likelihood of the development of necrosis following operative reduction of the lunate it is impossible to judge the rôle of necrosis (1-4, 10). There seem to be no

published reports of the development of Kienbock's disease following operative reposition of the lunate even when the bone was completely detached and the lesion treated late. No reference has been made in literature to the appearance of necrosis following manipulative reduction even when the bone was apparently completely free. On the other hand it would be logical to expect necrosis when the lunate has been cut off from its circulation just as in cases of fractures of the navicular. Necrosis is a factor which must be considered in selecting the operative form of treatment for a dislocated lunate bone.

The majority of surgeons advise operative reduction in selected cases using as a guide the time element and the local pathology. If the carpal bones show no gross changes if the ligaments and tissues are little retracted and if the lunate can be replaced without too much traumatism and maintained in position without flexing the hand acutely, operative reduction is indicated. The retention of the hand in acute flexion must be avoided because of the danger of the development of avascular necrosis during the long period of time that would be required for the hand to recover from this position. Operative reduction is more likely to succeed in incomplete dislocations than in complete luxations due to the fact that there are sufficient ligamentous attachments to ensure an adequate blood supply to the lunate.

Surgeons differ in their opinion as to when the hope of operative replacement should be abandoned. The writer as a rule would not attempt operative replacement in a case of more than 6 weeks standing since after this period the reactive organization at the site of the injury would interfere with replacement. Some surgeons on the other hand attempt operative reduction within the 2 month period after injury and others advise it as late as 6 months. Still others object to open reduction after the first 2 weeks believing that later than this period it is difficult to suture around the lunate sufficiently to hold it in position.

Although hard and fast rules cannot be laid down in general the following indications for operative reduction of the lunate may be recognized. Operative reduction is the treat-

SURGERY GYNECOLOGY AND OBSTETRICS

ment of choice when a dislocation that is seen within 2 weeks of the injury cannot be reduced by manipulation with a minimum of trauma. Operative replacement is the best method of treatment in a dislocation that is seen between 2 and 6 weeks after the injury. In cases of more than 6 weeks standing operative excision of the lunate is indicated. When there is any question as to whether operative reposition or excision of the lunate is preferable it is better to remove the lunate.

The technique of operative treatment is as follows. After the administration of a general anesthetic, a tourniquet is applied on the upper arm. A dorsal incision over the area of the lunate bone is used in any case in which reduction appears to be possible. This exposure is preferable to the anterior exposure for the following reasons. It leads directly down on the lunate avoiding tendons, vessels, and nerves and requires no cutting of ligaments. Moreover the dorsal approach avoids any difficulty in healing such as the development of a keloid on the wrist which may occur when the anterior approach is used owing to the flexed position in which the hand must be maintained following reduction.

The incision is about 2 inches in length. The fascia is divided and retracted thus exposing the cavity of the lunate bone. The space to receive the lunate is prepared by applying traction on the hand and cleaning out the cavity. The lunate is then readily reduced. Any remaining remnants of the dorsal radiocarpal ligament are sutured. The fascia and skin are closed. The hand is then carried into flexion and maintained in the degree of flexion that ensures reduction. The after-care follows along the same line as that of perilunar dislocations reduced by manipulation.

In dislocations in which the question arises of excising the lunate bone the anterior approach should always be used as it is difficult to remove the bone through the dorsal exposure. An anterior incision 2 inches in length is made over the site of the lunate bone. The incision is carried down through the fascia and the anterior annular ligament. The flexor carpi radialis is retracted to the radial side and the median nerve and palmaris longus and flexor sublimis and pro-

fundus digitorum tendons are retracted to the ulnar side. The space for the lunate is opened up by hyperextending the hand and the cavity cleaned out. An attempt is made to slip the lunate into place and if successful, the remnants of capsular tissue and the volar radiocarpal ligaments are sutured if possible. If reduction is not easily accomplished the bone is excised. The annular ligament and fascia are sutured and the skin wound is closed with interrupted silk sutures.

The hand is immobilized in the position of flexion if reduction has been possible and the same after-care is carried out as described under manipulative reduction of perilunar dislocations. If the lunate has been excised the hand is hyperextended from 5 to 8 degrees and maintained in this position for 3 weeks. An anterior plaster shell extending from the knuckles to the elbow is used for fixation. Exercises of the fingers should be carried out during the period of immobilization.

The treatment of dorsal dislocations of the lunate bone. The unusual dorsal dislocation of the lunate bone is treated along the same lines as volar dislocations. If the case is seen early manipulative reduction is attempted. If the operator forcing the wrist into flexion applying traction on the hand and pressing the lunate bone back into position when the gap has been created to receive it. The wrist is then forcibly hyperextended. A posterior plaster shell extending from the knuckles to the elbow is applied with the hand slightly dorsiflexed. Immobilization is continued for 3 weeks. Use of the fingers is continued during the period of fixation.

Dorsal dislocations that are irreducible by manipulative methods, and cases of long standing are treated by operative reduction or by excision of the lunate through the dorsal approach. The same indications being recognized and treatment being carried out according to the same principles as outlined under the management of volar dislocations.

The treatment of dislocations complicated by fracture of the navicular bone. The treatment of these complicated dislocations depends upon the time element, the local pathological condition, and to a certain extent upon the age of the patient. If the case is seen early

and the accompanying damage is not severe a fresh fracture-dislocation of either the perilunar type or of the lunate itself may be reduced by manipulation the same maneuvers being carried out as in the reduction of a simple dislocation. The replacement of the navicular fragment takes place simultaneously with the replacement of the lunate bone. The hand is immobilized in as near the neutral position as possible and the period of fixation is extended to allow time for healing of the navicular. At least 10 weeks are required and even a period of 3 months may be necessary to obtain firm bony union. The fingers should be used freely throughout the period of immobilization.

In complicated dislocations of the lunate in which manipulative reduction is unsuccessful and in cases of long standing excision of the lunate bone and the proximal fragment of the navicular is the treatment of choice. Operative reduction in such cases is to be avoided because of the difficulty of execution and the danger of further interfering with the circulation. Following excision an anterior plaster shell extending from the elbow to the knuckles is applied with the wrist in the position of 5 degrees hyperextension. The patient is encouraged to use his fingers within a few days. Immobilization by means of the plaster shell is continued for 3 weeks and then a protective adhesive strapping or a leather wristlet is worn for several weeks.

The older patient who sustains a complicated fracture-dislocation of this nature undoubtedly obtains a more useful hand if the wrist is arthrodesed. Manipulative reduction operative reduction or excision of the bones is likely to be followed by a periarthritis of the wrist.

PROGNOSIS

In general the uncomplicated dislocation that can be reduced by manipulation is followed by complete recovery of function within a few months. Good results have been reported following operative reposition of the lunate bone. Rauber (20) has reported one of the largest series of operative reductions and such was his experience that he concluded excision of the lunate is often decided upon too quickly.



Fig. 5 H. S. a, left, A dorsal perilunar dislocation of carpal bones with an associated fracture of the radial styloid process, of 1 month's duration. b, Roentgenogram taken 9 months after manipulative reduction. Note the general atrophy which may be a part of these injuries.

The results of excision of a dislocated lunate bone for the most part are fairly satisfactory. Neither the function nor the strength is equal to that of the normal wrist but the motion is satisfactory and the wrist and hand can withstand moderately heavy work. Pain is usually entirely relieved. Recovery in these cases depends to a great extent upon the presence or absence of a tenosynovitis of the flexor tendons or damage to the median nerve or periarthritis.

The prognosis in fresh dislocations complicated by a fracture of the navicular is not so favorable as in simple dislocations. Here the possibility of nonunion and necrosis of the navicular must be considered. A good recovery is more likely to be made following early manipulative treatment.

In older patients and especially when there is any arthritic involvement the prognosis in either the perilunar dislocation or luxations of the lunate must be guarded regardless of the efficacy of treatment. Many of these dislocations are complicated by severe damage to the capsular tissue and ligaments periosteal



Fig. 6 W. K. a. Fresh dorsal perilunar dislocation of carpal bones complicated by fractures of navicular and both

styloid processes. b. Roentgenogram taken 14 years after manipulative reduction. Vascular compromise considered.

tears small chip fractures and disturbance of the blood supply factors that cannot be eliminated by any form of treatment. It is not unlikely that a traumatic arthritis of the wrist and carpal joints may develop causing the hand to be swollen and weak and the motion limited.

In untreated cases the prognosis is poor as to the function of the entire hand. Motion of the wrist and fingers is limited due to the blocking by the dislocated bone or bones and to the presence of chronic swelling of the tissues. The fingers are usually permanently swollen and the hand becomes atrophied from disuse. The patient complains of pain and numbness in the fingers symptoms that are indicative of pressure on the median nerve.

CASE REPORTS

The series includes 24 cases. Twenty three of the patients were men a distribution that is to be expected since man is exposed to injuries in his work. The only woman was a circus performer. Seven patients had fallen from a height, 3 from stagings, 2 from trees, 1 from a window and 1 from a trapeze. All

had landed on the outstretched hand. Three patients had fallen on the ice, 1 had injured the hand in an automobile accident, 1 in an airplane crash, 1 in a motorcycle accident, 1 had caught the hand in a machine, and in 1 case the injury had been the result of the recoil of the crank of a motor. In the 9 other cases the origin of the injury was not recorded. The right and left hands were equally involved. One case was bilateral.

Fourteen of the 24 lesions were of long standing that is from 3 weeks to 13½ years when they first came to the attention of the writer. Most of the patients had consulted a physician at the time of the injury, but they had received no definite treatment. One dislocation had been manipulated unsuccessfully 5 weeks after the injury. All 14 patients were complaining of continued disability due to pain, swelling, and limited motion of the wrist and hand. The delay in the treatment of 14 of 24 cases clearly brings out the fact that these lesions are either overlooked or the treatment is inadequate in the early stage.

The following dislocations are included in the series: 5 fresh dorsal perilunar dislocations

MACAUSLAND DISLOCATION OF CARPAL AND LUNATE BONES

of the carpus 3 dorsal perilunar dislocations of long standing, 1 fresh anterior perilunar dislocation and 4 fresh volar dislocations of the lunate bone 11 volar dislocations of the lunate bone of long standing

Six of the 9 perilunar luxations were complicated by fractures in 3 cases by fractures of the navicular either alone or in combination with fractures of the styloid processes and in 3 cases by fractures of the styloid processes Eight (1 bilateral case) of the 15 dislocations of the lunate bone were complicated by fracture of the navicular and 2 were associated with fractures of the styloid processes The frequent occurrence of a concomitant injury in this series bears out the observation that a fracture is a common finding

Six of the 9 perilunar dislocations were treated either on the same day as the injury or within a few days Manipulative reduction was successfully carried out in 4 of the 6 cases. One case following the failure of manipulative treatment was reduced operatively and open reduction was advised in the other case but was refused by the patient

The 3 perilunar dislocations of long standing which were all of the dorsal type were treated from 3 weeks to 1 month after the injury Circumstances appeared to be favorable to manipulation in 2 cases in 1 of which the procedure was carried out successfully In the other case the closed reduction failed and the dislocation was reduced operatively

The third case of dislocation was reduced successfully by the operative method In 2 of the 4 fresh volar dislocations of the lunate bone all of which were seen within 2 weeks of the injury an attempt at closed reduction was made but in only 1 case was it successful In the 2 other cases excision of the lunate was the primary treatment because of the extreme displacement of the bone

The 11 volar dislocations of the lunate bone of long standing that is ranging over a period of from 3 weeks to 1½ years were treated by excision of the bone The majority of these cases were treated several years ago when excision tended to be the accepted treatment and in the light of our present knowledge operative reduction undoubtedly would have been attempted in some of the cases. In 5 of

these dislocations of long standing in which there was a concomitant fracture of the navicular bone the proximal fragment of the navicular as well as the lunate bone was excised and in 1 case (a bilateral case) both lunate bones and the entire navicular bones were removed

Results It was possible to check the results in 19 of the 24 cases after a considerable length of time in the minimum after 1 year and in the maximum after 27½ years The average period of observation was 8 years All patients were requested to report for examination of their wrists and when this was impossible to send a detailed account of the condition of their wrist and hand

The 9 cases of perilunar dislocations were checked after a period varying from 1 to 13½ years Two patients could not be traced Five results were good including 2 cases that had been treated by manipulative reduction (Fig 5) 1 case that had been reduced operatively at the time of the injury and 2 cases that had been treated by operation following unsuccessful attempt at manipulation One of these patients is working in a metal plant and handling heavy coils The patient whose wrist had been treated by operative reduction secured an excellent result and when the wrist was examined 2½ years after reduction it was withstanding heavy work in a defense plant In another case the only defect is a limitation of 10 degrees in the extension of the wrist (Fig 1) In 1 case that was treated by manipulation the alignment is good but the navicular remains ununited (Fig 6) In the remaining case that of volar luxation the result is unsatisfactory The motions of the hand being limited and painful This dislocation had been reduced successfully by manipulation at the time of the injury but 3 months later the lunate bone had dislocated and excision was necessary (Fig 2)

The 4 cases of fresh volar luxation of the lunate bone were checked from 7 to 21½ years after treatment The patient who had been treated 21½ years previously had died In the 3 other cases 2 of which were treated by primary excision and in 1 of which excision followed unsuccessful manipulation good results were obtained 1 patient is a state

SURGERY GYNECOLOGY AND OBSTETRICS

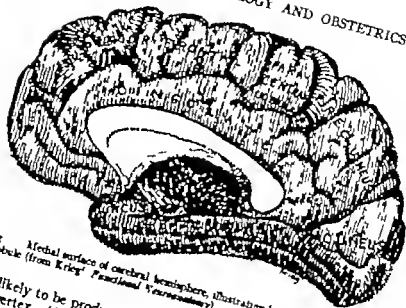


Fig. 1. Medial surface of cerebral hemisphere, illustrating location of the paracentral lobule (from Krieger' Functional Neuroanatomy).

the injury is more likely to be produced by a direct blow to the vertex. Although in many cases the outer table is undepressed and there is a depression of the inner table in most instances both tables are depressed. This latter defect causes a spoon-shaped depression in the skull and it is almost invariable that the injury is far more extensive than the roentgenograms of the skull indicate. Depressed

fragments usually merely compress the sinus or its lacunae but the walls of these vessels may be lacerated and fragments of bone driven into the adjacent paracentral lobules.

Exposure of the superior longitudinal sinus in such cases usually reveals the presence of a thrombus in the sinus. However the venous obstruction is rarely complete because of the divisions of the sinus by irregular transverse trabeculations its rigid walls, and the support offered to it by the dura mater. If the injury is more lateral the thrombus may be limited to the venous lacunae beneath the lesion.

Autopsy studies (Holmes and Sargent) showed that the superficial cortical veins which entered the sinus near the wound were thrombosed, and that there was congestion of the neighboring veins with edema of the adjacent brain. Section of such brains demonstrated edema and hemorrhages in the neighborhood of the wound and in some cases actual softening near the medial sinus.

Occlusion of a cerebral vein has been shown to cause the following microscopic sequence: Congestion and thromboses in the cortex followed by sharply demarcated nets of hemorrhages, and finally, confluence of the latter progress to cause encephalomalacia in severe cases or may regress to recovery when the circulation of blood is re-established.

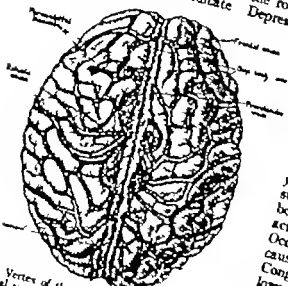


Fig. 2. Vertex of the cerebrum showing the superior longitudinal sinus, lateral lacunae, and superior cerebral veins (from Bailey' Intracranial Tumors).

Circulatory disturbances in the paracentral lobules may be caused by a number of conditions other than traumatic lesions. Neoplasms particularly the parasagittal meningiomas (Bucy) thrombosis of a superior cerebral vein without involvement of the superior longitudinal sinus (Waggoner Merwarth and Dowman) and thrombosis of the anterior cerebral artery (Winkelman Ornsteen and Wilson) are a few among such lesions.

PHYSIOLOGY OF THE PARACENTRAL LOBULES (FIG 3)

As early as 1893 von Bechterew working with dogs localized the cerebral centers for the rectal and urinary sphincters in the sigmoid convolution a region which is comparable to the paracentral lobule of man. Little information was contributed from this time until World War I when Kleist and others observed cases of injury to the paracentral region which were characterized by a loss of control of voluntary micturition paraplegia and little or no change of consciousness. The observations of Langworthy Lewis and Dees (19) suggested that one hemisphere was dominant in the control of the bladder and that this inhibitory center was close to the top of the motor convolution near the nerve centers for the foot (Gruenbaum and Sherrington). In man the extirpation of one paracentral lobule (right or left) has no apparent effect on micturition (Bucy). This function seems to be subservient to bilateral control of this portion of the cerebrum.

With respect to the remainder of the mechanism apart from the paracentral influence the work of Hunsicker and Spiegel showed the existence of a double conduction system pyramidal and extrapyramidal of corticofugal impulses to the spinal cord. Both centripetal and centrifugal pathways are situated in the dorsal half of the lateral column of the spinal cord near its periphery (Barrington). The lumbosacral segments of the spinal cord contain all of the nervous mechanisms for micturition except those which decide whether its occurrence would be appropriate for the environment (Denny Brown 6). It is prob-

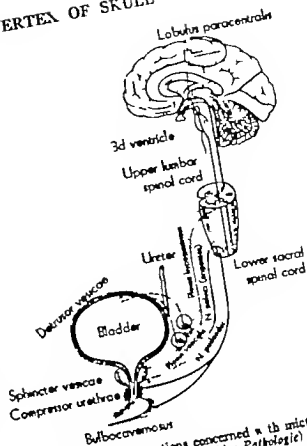


Fig. 3 Neural connections concerned in micturition (from L. R. Mueller in Kleist & Gehlen *Pathologie*)

able however that the sympathetic system exerts its influence solely through the medium of the circulation and the parasympathetic system through the innervation of the smooth muscle (Langworthy 16).

The activity of some of the muscle which is innervated by the parasympathetic nervous system (e.g. the bladder and rectum) is closely correlated with the movements of striated muscle (Denny Brown and Robertson 7). These authors expressed the opinion that contraction of the external striated muscle sphincter of the bladder leads reflexly to suppression of waves of contraction in the vesical muscle and that voluntary micturition was begun by relaxation of the striated muscle of the perineum followed by strong contraction of the vesical muscle. The rectum and pelvic colon moreover show spontaneous contractions which activity of the bladder tends to stimulate. The paracentral lobules apparently possess somatic and autonomic centers in close topical relationship. Thus the skeletal muscle of the more distal segments of the lower extremities and that of the external sphincter of the urethra and anus is controlled

by centers which are closely related to those for the smooth muscle of the urinary bladder rectum and pelvic colon.

Waves of contraction in the vesical muscle may be suppressed voluntarily in man. Stimulation experiments in animals revealed that vesical contractions were suppressed at times, and initiated at other times. Damage to these centers in the paracentral lobules may be manifested by an inability to initiate or to stop micturition voluntarily or by an inability to appreciate bladder distention (Langworthy and Kolb 23).

A period of "shock" follows interruption of the cortico-spinal pathway in man and in cats and the subsequent retention of urine may necessitate catheterization (Langworthy and Hesser 17). With recovery the tonic mechanism in the midbrain when released from cortical control becomes hypersensitive. This causes an increased activity of the stretch reflex with incontinence or urgency or urination, the strength of the striated muscle of the external sphincter of the urethra being comparable to the increased tone of the muscles of the extremities.

The following cases illustrate clinical pictures of depressed fracture of the skull localized to the bilateral paracentral region.

CASE REPORTS

CASE 1: G. O., a 40 year old workman, was struck on the top of the head by a 30 pound iron bar which fell from a distance of about 35 feet. The injury occurred at noon on March 4, 1910. He is said to have been unconscious for minute or two. He was examined 30 minutes after the injury by Dr. D. E. Dick (of Geneva, Ill.) who found him fully conscious and rational. He was admitted to the St. Charles City Hospital at 1:00 p.m.

There was a scalp laceration 6 centimeters long over the middle of the vertex of the skull, extending chiefly toward the left side. Upon the cleansing of this wound, fracture of the vertex of the skull could be seen, and a small amount of macerated cerebral tissue extruded. In addition to the above cranio-cerebral injury the patient also complained that he could not move his legs and that they were numb. The knee and ankle jerks were present and equal. By about 5:00 p.m. motion was just beginning to return in the right leg and also some sensation. In order to treat properly the possibility of an associated back injury several pillows were placed beneath the patient thereby extending his back. The major complaints at this time were headache of the

ness of the bladder, soreness of the back, and the motor and sensory disturbances of the legs.

He was seen by one of us (E.O.) in consultation at 8:30 p.m., the evening of the injury. At this time the patient was found to be lying in bed with reasonable comfort and to be perfectly conscious and rational. The head dressing was not disturbed. The patient was normal from the neurologic viewpoint, except for the lower extremities. Motion in the right leg was fairly good but the patient stated that he could not move the left leg at all. This paralysis involved the foot, lower leg, and thigh. Sensation however had returned in both lower extremities. The knee and ankle jerks were bilaterally present, equal and active. There was no Babinski sign on either side. The patient stated that he had not voided since the time of the accident and that there was a feeling of distention of the bladder. He believed that he would be able to void spontaneously however. He also complained of some pain in the lower lumbar region. Because of the presence of a compound skull fracture over the Rolandic area, it was believed that the initial paraplegia was cerebral in origin. However it was also kept in mind that a cranio-cerebral injury might be complicated by an associated injury of the back. The treatment given was conservative.

By 10:00 p.m. it was seen that the right leg was slowly improving in strength. The patient complained rather bitterly about retention of urine and, accordingly, heat was applied to the pubic region. With considerable effort he was able to void spontaneously 700 cubic centimeters of urine, nearly 24 hours after the injury and after 6 hours of uncomfortable bladder distention. Again at 11:30 a.m. the next morning, he voided spontaneously as he did normally thereafter. No abnormal depression of consciousness was observed at any time.

Portable roentgenograms of the skull and lumbar vertebral column were made. A U-shaped depressed fracture about 2 inch in depth over the vertex of the skull on the left side was seen. The wound was allowed to heal and operative interference was delayed. The patient improved slowly. Three days after the injury examination revealed that function had returned quite completely in the right leg, but that voluntary motion was still absent in the left leg. He suffered from periodic attacks of headache and vomiting during the first 5 days. On March 31, 1910 (7 days after the injury) motion in the left leg began to return. Flexion of the thigh and leg returned first, and 6 days later motion in the foot was possible for the first time since the injury. At the time of his discharge on April 16, 1910, motion was normal in the right leg, sensation had returned completely and the left leg was moderately paretic.

He was admitted to St. Luke's Hospital, Chicago on May 6, 1910. The left leg had improved but still was weaker than the right and showed a Babinski sign and clonus of the ankle. Examination showed a depression of the vertex of the skull, a shallow crater-like defect which measured 4 centi-

GREEN OLDBERG INJURIES OF VERTEX OF SKULL

TABLE L.—SUMMARY OF POSTOPERATIVE RECOVERY CASE 2

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Date	General symptoms	Motion	Sensation	Bladder, rectal, sexual functions
3-6-4 (post-operative)	Increase suboccipital headache. Short periods of motor aphasia	Right central facial paresthesia (complete) Unable to raise head	Common sensation intact. Stereognosis bilaterally	Catheterized at 10 p.m. 450 cc of urine. Bladder sensation normal. Impotent
3-17-4	Headache	N change	N change	Voided spontaneously at 4 a.m. noon and 4 p.m. N residual
3-18-4	Headache. Intermittent pains of arm and legs	Facial weakness improved. Arms less rigid. Slight extension of right arm	Return of stereognosis. Ability in left hand	N change
3-20-4	Headache mild	8 p.m. Voluntary motion in left thumb. partial extension of right arm. Voluntary motion of both hands returning	Return (partial) stereognosis. Ability in right hand	N change
3-20-4	N complaints. Profuse diaphoresis	All movements of hands and fingers, left, right. Flexion of right elbow	Stereognosis ability almost normal	N change
3-21-4	Abdominal distention. Diaphoresis	Cas turn head from side to side. Return of neck and head motions	Normal	N change
3-24-4	Mild diaphoresis	Shoulder motion on left side. Neck and head motions	Normal	N change
3-26-4	N complaints	Able to sit up, hold newspaper and feed himself. Hands almost normal. Flexion of right thigh	Normal	Erection for first time since injury. Still impotent
4-7-4	Mild diaphoresis	Slight flexion of left thigh of both thighs	Slight extension	Feces potest
4-7-4	Feces fine	Flexion of right leg	Normal	Normal
4-6-4	N complaints	Arms normal. Motion in trunk and proximal portions of legs fair. Slight flexion of left foot. N motion in toes. Bilateral stable clonus for first time. Legs less spastic	Normal	

meters in length. Roentgenograms were made (Fig 4) and a depressed fracture was apparent in the vertex near the midline and also slightly to the left. An area of about 6.5 centimeters of bone was seen to be depressed below the inner table.

On May 13, 1940 (3 months following the injury) the patient was reflected to expose the depressed flap of scalp was reflected. The bone was excessively vascular and overlaid the sagittal sinus. Accordingly a burr hole was made on the left side and thus per burr hole was made on the depressed bone in two fragments. The fragments measured 3 by 2 by 0.5 centimeter and 1.8 by 0.6 centimeter. After some time hemostasis was obtained and the wound was closed. The postoperative course was uneventful. The sutures were removed on May 16, 1940 and the patient was sitting up and walking about in the ward for 2 days before his discharge from the hospital on May 19, 1940.

Five months later examination showed improvement. The patient walked with a cane reasonably well and reported that he had been able to use a lawn mower recently and was very pleased with his progress. His left leg was quite weak and spastic. He desired to return to work but was unable to do so because of his inability to climb a flight of stairs which led to his place of work. It was learned that on October 16, 1940, this patient had committed suicide.

CASE 3. E. A. 34 year old Pfc. in the U S Army was on leave when he was struck on the crown

of the head by the edge of a plate glass window pane which fell from a window 40 feet above. The injury was sustained at 11:00 a.m. March 9, 1942 and he was admitted to St. Luke's Hospital at 11:55 a.m. He was said to have been only momentarily dazed. He was said to have been only momentarily dazed. He was said to have been only momentarily dazed. He was said to have been only momentarily dazed.

At the time of admission to the hospital the patient from a laceration across the vertex of the scalp and to have suffered immediate paralysis of both legs. At the time of admission there was no headache or responses were normal and there was no headache or other discomfort. The blood pressure was 130/86. There was a jagged laceration about 10 centimeters in length across the crown of the forehead. The one about 4 centimeters long on the forehead. The skin was very pale, cool and moist. The cranial nerves were intact. Mobility of the neck was not ascertained because of a fracture or fracture-dislocation of the cervical region had not been ruled out. The speech and right arm were normal (he was right handed). The left arm was spastic and somewhat rigid but movements of the wrist and hand were preserved. Both legs were rigid in extension and all voluntary motions were lost. The deep reflexes in the left arm and both legs were increased. No pathological reflexes were elicited. There were equivoal and bizarre areas of hyperesthesia below the level of the clavicles. Four hours following the injury the patient complained of a strong desire to void but was unable to do so and 400 cubic centimeters of normal urine was obtained by catheter.

The immediate treatment consisted of bed rest fixation of the head with band in a position of

TABLE II.—DIFFERENTIAL DIAGNOSIS OF INJURIES OF THE SPINAL CORD AND BOTH PARACENTRAL LOBULES

Clinical features	Spinal cord	Paracentral lobules
Cause	Fracture or dislocation of vertebrae	Depressed fracture of vertex of skull near Rolandic areas
Motor signs		
(1) Early	(a) "Spinal shock" with flaccid paraplegia for days or weeks	(a) "Cerebral shock" with transient flaccid paraplegia for hours or days
(b) Later	(b) Spastic or flaccid paraplegia, signs usually reach maximum within a few hours	(b) Spastic paraplegia with early remarkable rigidity. May develop triphasic or quadriphasic and rostral systems, over period of days
Sensory changes	Distal segments of upper extremities and proximal segments of lower limbs and perineal area	Proximal segments of arms and distal segments of legs suffer most and recover last
	May have complete loss of sensation in all modalities below level of lesion. Pain sensibility almost always destroyed	Cervical type of sensory loss. Pain and temperature sensibility is rarely affected, stereognosis and stereognosis are constant
Autonomic signs		
(a) Bladder	Early. Retention of urine and feces. Pain sensibility usually lost. Priapism common in severe injuries	Early. Retention or incontinence of urine and feces. Pain sensibility preserved. Priapism is uncommon
(b) Rectum, and		
(c) Genital	Later. Slow recovery to normal or subnormal control of bladder. Gradual return of rectal and genital power	Later. Rapid recovery of bladder function in most cases unless involvement of both paracentral lobules occurs. Potency returns at about same time as rectal and genital muscles
Lumbar fracture		
(a) Pressure	Normal	Normal or elevated
(b) Dynamics	Normal or incomplete or complete subarachnoid block	Normal
(c) Color	Clear blood-stained or xanthochromic	Clear blood-stained or xanthochromic
Roentgenograms		
(a) Skull	Normal	Depressed skull fracture in or near Rolandic areas
(b) Vertebrae	Fracture or fracture-dislocation	Normal, an associated cervical fracture may be present

slight extension and the administration of hypertonic fluids. Six hours following the injury the scalp was shaved and the wound cleaned and debrided. The entire crown area of the scalp was exceedingly edematous, the galea aponeurotica was apparently intact and the examining physician in the emergency admitting room specifically stated that he had seen no evidence of skull fracture; the depth of the wound. Accordingly following irrigation with physiological saline he had applied approximately grams of sulfanilamide and closed the wound with black silk sutures. The small laceration on the forehead was closed similarly. Tetanus antitoxin (500 units) was also given. Portable roentgenograms of the cervical region were made and revealed a pathological change.

Seven hours following the injury the patient again experienced a desire to void and spontaneously urinated 100 cubic centimeters but from this time onward he was unable to void, in spite of the fact that he apparently possessed normal sensation in the bladder. He also complained of a feeling of impotency and of difficulty in defecation. The sphincter difficulties persisted unchanged until his operation of March 6, 1941, one week later.

On March 11, 1941, the patient complained of photophobia and of loss of all motion of the left arm, with the exception of motion of his fingers. He still had neither mental symptoms nor headache. A lumbar puncture was made. The initial pressure was found to be 5 millimeters of water, the dynamics were normal. After the removal of 7 cubic centimeters of blood tinged xanthochromic fluid, the pressure was 30 millimeters of water.

Four days following the injury paresis of the right arm became apparent. Motion of the shoulder and elbow was lost, and only slight motion of the fingers was retained. The arm was also moderately spastic and rigid. Myoclonic contractions of the muscles of the right arm and both legs were frequent. There were no definite sensory changes, aphasia nor loss of stereognostic sensibility.

Five days following the injury the patient experienced slight twitchings of the eyelid and corner of his mouth on the left side and also a period of inability to speak for approximately 20 minutes. He was unable to raise his head from the pillow and complained of photophobia. Tetraplegia was unchanged. The following day (Sunday March 15, 1941) he appeared somewhat lethargic for the first time. There was also a partial paresis of central type on the right side and astereognosis of the right hand. Portable roentgenograms of the skull were made and showed a marked depressed fracture of the skull over the Rolandic area of the brain (Fig. 5). This fracture crossed the midline transversely and extended 3 centimeters to the right, 5 centimeters to the left, and about 8 centimeters anteriorly. The anterior portion of the fractured bone was depressed and broken into a number of fragments. The laceration of the scalp was fairly well healed and it was considered to be injudicious to temporize longer.

On March 16, 1941, utilizing local anesthesia a horse-shoe-shaped scalp flap was made over the central region. On exposure of the affected area it was found to be depressed at least 1 centimeter and to be sufficiently shattered to be removable by blunt



Fig. 4. Roentgenograms of skull in Case 1: a, left, Posteroanterior view and, b, lateral view. Note depressed fracture of vertex, near Rolandic area of brain.

dissection. Eight fragments were removed and these included pieces varying in size from 1.2 by 0.5 by 0.5 centimeter to 5.5 by 2 by 0.5 centimeter. When the bone had all been removed the dura mater was found to be intact except over an area just to the right of the sagittal sinus. This area was about 3 centimeters in diameter and macerated brain protruded through it. The wound was treated with sulfanilamide powder and closed with black silk suture material. A summary of the post operative recovery is shown in Table I.

He was transferred from St. Luke's Hospital on April 20, 1943 to Fort Sheridan, Illinois. Re-examination (E.O.) on November 3, 1943 at the Billings General Hospital, Fort Benjamin Harrison, revealed the following findings. The scalp was well healed and there was a sunken defect about 3 centimeters in diameter over the vertex of the skull where the operation was performed. The patient stated that sphincter control was normal, as was his sexual power. The present vision was 20/20 in the left eye and 20/30 in the right. The patient felt that his hands were awkward in fine movements such as those used in dealing cards but were otherwise normal. The patient was using a brace on the left lower leg and ankle because of lack of power in the ankle causing a toe drop. The sensorium was normal.

Examination showed a well built man who apparently had gained some weight. He was alert and well oriented. There was no complaint of headache or dizziness. All cranial nerves were normal and all of the usual tests of the upper extremities were normally performed and the reflexes in these extremities were normal. The epigastric and abdominal reflexes were absent. The disability was confined to the lower extremities. There was no atrophy here but there was weakness more marked on the left and there was very slight motion of the left ankle joint. The knee jerks were bilaterally exaggerated with patellar clonus. The ankle jerks were within normal limits and there was no ankle clonus nor was there any Babinski or Oppenheim sign.

CLINICAL CONSIDERATIONS

Traumatic lesions which occur in the region of the vertex of the skull may injure the paracentral lobules directly or cause damage indirectly by means of venous obstruction. It is remarkable that the majority of cases (Kleist, Holmes and Sargent) like our own show so little change in consciousness. This fact in association with the loss of function of the legs, bladder and rectum may initially suggest to clinicians the presence of pathology in the spinal cord, rather than in the cerebrum. The symptoms and signs of increased intracranial pressure are usually lacking although many of the patients complain of headache and this may further direct attention away from the actual site of injury.

The site, severity and extent of the motor symptoms are unusual and were first pointed out by Holmes and Sargent. In the upper extremities the proximal segments are the most severely affected and recover last. The muscles of the back are frequently involved as in our Case 2 so that the patient can neither sit up nor move about in bed. The paralysis of the legs is the converse of that in the arms, thus the distal segments suffer most and recover last. Damage to the nerve cells for the more distal segments of the legs is apt to occur first because occlusion of the veins is more apt to occur here in these smaller vessels which drain from the apex of the hemisphere and then to spread laterally to a varying degree. The marked rigidity of the affected extremities

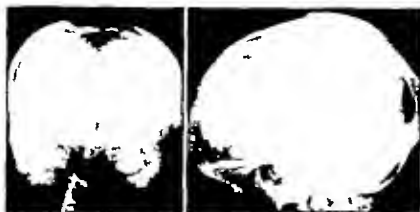


Fig. 3 Roentgenograms of skull in Case 1. a, left, Posteroanterior view and, b, lateral view. Depressed, fragmented fracture of skull over Rolandic area of brain.

is a striking feature and was interpreted (12) to be secondary to pure cortical paralysis, unaccompanied by any effect of shock on the subcortical centers which control the tone of muscles. The more recent work of Kennard and Fulton concerning the function of area 6 (which is just anterior to the paracentral lobule) seems to offer the most plausible explanation of the muscular rigidity which is so characteristic of severe lesions in the paracentral region. Both of our cases showed a paraplegia at the onset. Improvement was rapid in Case 1: the right leg recovered quite completely within 3 days and the left leg improved slowly over a period of months. On the other hand the injury was more severe in Case 2 and a quadriplegia developed within a few days following the initial paraplegia and was not relieved until after the decompressive operation had been performed upon the patient.

The association of motor and autonomic disturbances (e.g. dysfunction of urinary bladder rectal and sexual mechanisms) with these lesions has received little emphasis. World War I produced several outstanding reports. Although bladder dysfunction was noted in a certain number of the cases of Holmes and Sargent rectal and sexual derangements were barely mentioned. The majority of the patients with disturbances of the bladder experienced some difficulty in micturition or even retention of urine (like our cases) but this almost always disappeared

quickly. Incontinence was of less frequent occurrence. The usual sequence of events is as follows: first, retention of urine, which may disappear spontaneously as in Case 1 recover almost immediately after operation, as in Case 2 or be progressive. If there is more permanent damage. Following a short period of overflow incontinence the bladder may recover or become uninhibited and hypertonic. It was concluded by Kleist that only if the deepest portions of both paracentral lobules or their efferent pathways are injured, can bladder disturbances be shown. He called attention to the disturbances of rectal function (involuntary movements or obstipation) in these cases. Similar symptoms and signs were noted by Wilson and in his Case IV he records the paralysis of sexual function in addition to the loss of use of the legs, bladder and rectum. Potency in his case returned with the recovery of the sacral muscles whose nerve centers are represented in the paracentral lobules. Our Case 2 also regained his sexual powers at the same time as the recovery of the adjacent striated muscle.

From the foregoing discussion it is readily seen that many cases may offer some confusion in the differentiation of cerebral and spinal pathology (Table 11). Furthermore a number of cases of injury of the spinal cord also have associated craniocerebral injuries and vice versa. Figure 3 is a chart which outlines the differential features which may offer themselves.

CONCLUSIONS

- 1 Two cases of bilateral injury to the paracentral lobules of the brain are presented
- 2 The influence of such lesions on sphincter control is reviewed and discussed
- 3 The superficial clinical similarity of the symptoms and findings of spinal injuries and those of both paracentral lobules is pointed out and suggestions regarding differential diagnosis are made

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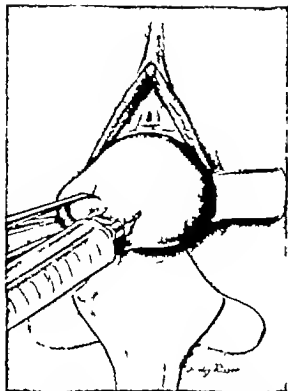


Fig. 1. Cervix exposed and grasped with tenacula.

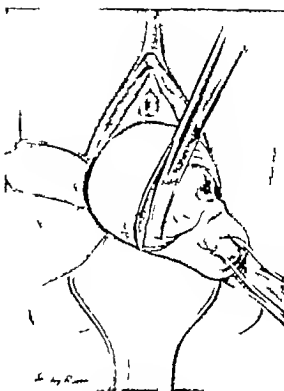


Fig. 2. Circumsection of cervix.

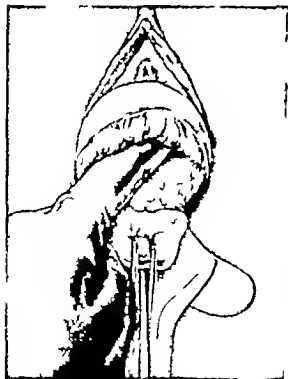


Fig. 4. The bladder is pushed off the cervix and laterally from base of each broad ligament.

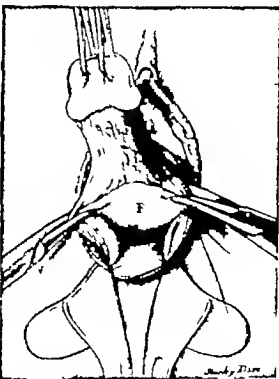


Fig. 5. The peritoneum overlying rectum approximated to posterior vaginal wall by interrupted sutures.

VAGINAL HYSTERECTOMY

An Evaluation of Gellhorn-Emmert Modification of the Dickinson Technique in 600 Cases

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VAGINAL hysterectomy has been attracting a great deal of interest in this country in the past 10 years a fact reflected not only in the fairly voluminous literature upon the subject but also in the increased geographical distribution of the contributions.

Many of the discussions are repetition and invariably deal with the volume of patients operated upon, the proficiency of the operator, the low morbidity and mortality rate, the negligible blood loss, or the ease with which the pathological conditions are met.

Elaborate statistical data covering age incidence, indications for the procedure, postoperative complications, etc., are given in detail; however, the startling fact remains that with two exceptions, this literature reveals a total lack of failures accompanying or following the procedure. Those individuals who fortunately did not contribute to the operative mortality rate of from 0.35 per cent to 0.45 per cent (Sfanev) lived happily with no recurrence and without the subsequent development of such trivial affairs as urethrocele, cystocele, rectocele, or enterocele.

These exceptions, the contribution of George Cray Ward who reports a follow up of his cases over a period of 16 years, and Phaneuf, ably demonstrate that recurrences can occur even in the best of hands, and under these circumstances are we not justified in expecting recurrences in the hands of those possibly not quite so capable?

The history of vaginal hysterectomy is one of evolution, a transition through successive stages of accomplishment and perfection in overcoming the two great obstacles, namely: (1) lack of exposure of the operative site, (2) the obscurity of anatomical detail due to a badly held

Without an attempt to review the older literature suffice to say that in this country Christian Fenger in 1881 described his first case in detail that gradual improvement in technique took place to 1915 when Charles Mayo described an operation designed to correct the vesical deformity accompanying uterine prolapse as well as to remove the uterus. This procedure has remained unchanged except for the modification as devised by Ward for prevention of enterocele.

The reports in literature deal mainly with the technique of the operation as devised by Mayo or a modification of the same, totally neglecting the undesirable sequelae occurring in a varying percentage of the cases. Apparently the follow up of these cases over a period of 3 years or longer has not been reported, and without this valuable information we are unable to evaluate the efficiency of a particular technique or to arrive at a basic conclusion as to its value in meeting the situation at hand.

What end results have we a right to expect from an operative procedure? (1) No recurrence of urethrocele, cystocele, enterocele, or rectocele. (2) preservation and maintenance of the vaginal canal.

It is the purpose of this paper to point out the end results obtained from our technique which has carefully been worked out over a period of 14 years, at the same time enumerating the course of failure and undesirable end results of other procedures.

TECHNIQUE OF THIS OPERATION

1. *Infiltration of the parametria*—The preoperative administration of morphine and hyoscine is used and the lower back is firmly strapped in order to prevent a sacroiliac strain from the extreme lithotomy position in which the patient is placed. The evening before the patient is given a sterile water douche followed

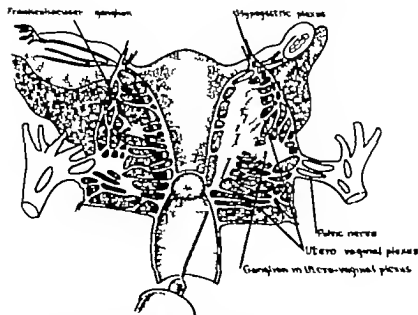


Fig. Diagram showing infiltration block of parametria and large sympathetic ganglion of Frankenhäuser

by an instillation of phenerol. The cervix is exposed and grasped with tenacula pulled down and to one side (Fig. 1). The needle of a 10 cubic centimeter syringe is inserted parallel with and alongside the cervix into the lateral fornix to a depth of 3 or 4 centimeters. Twenty cubic centimeters of 0.5 per cent novocain with adrenalin $3\frac{1}{2}$ drops to the ounce are injected while the needle is slowly withdrawn. The procedure is repeated on the opposite side.

Figure 2 shows diagrammatically how by this infiltration of the parametria the nerve supply of the uterus, particularly the large sympathetic ganglion of Frankenhäuser near the base of the broad ligament is blocked. After the two injections laterally infiltration of the anterior vaginal wall to the urethra and posterior vaginal mucosa is done. Local infiltration causes a marked blanching of the tissues, which makes the dissection easier and helps produce complete hemostasis. With the use of the automatic continuous flow anesthetic syringe there is little danger of injecting the fluid directly into the blood stream for as the plunger is pulled out if blood is seen in the container the needle must be withdrawn and reinserted.

2. *Circumcision of the cervix.* Demonstration of the vesicovaginal and vesicocervical spaces. With marked tension of the vaginal wall a complete circumcision of the cervix is made (Fig. 3). The level of the incision is slightly above the site at which the vagina becomes continuous with the cervix. This level may be recognized by the observation that the vagina above the portio is wrinkled whereas the mucosa appears smooth over the portio. The entire thickness of the anterior vaginal wall is incised and the cut must be perpendicular to the surface of the tissues. If the incision is made to the required depth the lips of the wound suddenly spread apart as the incision is completed. Through the wound may be seen the vaginal fascia, the surface of which is rough and covered with loose tissue with a characteristic red color. At the lateral edges of the anterior incision only the vaginal wall is incised, but in the middle portion the vaginal fascia should be divided transversely. As soon as this incision is made the vesicovaginal space is entered. The supravaginal septum extending from the bladder to the cervix now comes into view. It is also transversely incised, thus opening the vesicocervical space. With counterpressure by the anterior bayonet

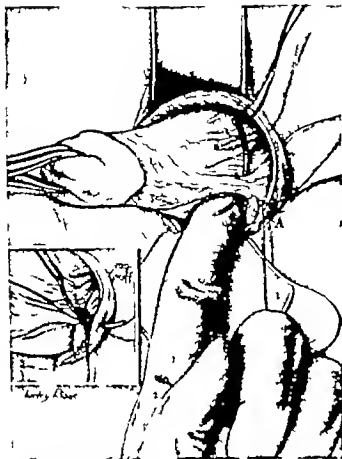


Fig. 6 Base of broad ligament exposed left uterosacral ligament has been ligated and cut.



Fig. 7 Inset shows how vessels are ligated with a square knot. Loose end of ligature held by Kelly clamp

retractor the bladder is pulled away from the cervix in this area. The bladder is then pushed off the cervix (Fig. 4) and laterally from the base of each broad ligament. The lateral boundaries of the vesicocervical space are the bladder septa that is the vesicouterine ligaments which stretch backward from the bladder to the Mackenrodt ligament. On each side the uterine vessels lie and may be seen mesial to the bladder septa extending downward at the edge of the uterus. The vesicocervical space may be opened upward as far as the anterior peritoneal fold. If the anterior bayonet retractor holds the bladder back it is possible to see the edge of the peritoneal attachment to the anterior wall.

3 (a) *Posterior cul-de sac opened exposing fundus uteri* (b) *peritoneum overlying the rectum is sutured to the posterior wall* (c) *left uterosacral ligament ligated prior to cutting*. The cervix is pulled toward the symphysis. Counter

pressure is made by the right and left Pfannenstiel retractors and the posterior weighted retractor thus causing tension of the posterior vaginal fornix. To open the posterior cul-de sac, the vagina and its fascia must be completely incised in the middle third of the posterior incision. At each side where the anterior and posterior incision meet, it must be remembered that only the vaginal mucosa is incised for if the incision is made deeper in these areas the veins of the vaginal plexus which lie in the vaginal fascia are cut resulting in unnecessary bleeding. The peritoneum of Douglas pouch is now transversely incised it is recognized by its white translucent appearance. The peritoneum overlying the rectum is approximated to the posterior vaginal wall by interrupted sutures (Fig. 5). They prevent troublesome bleeding from the posterior vaginal wall supplied by the hemorrhoidal vessels. The sutures are left long to serve as guides later in the operation. With the cervix still on tension two strong fibrous bands can

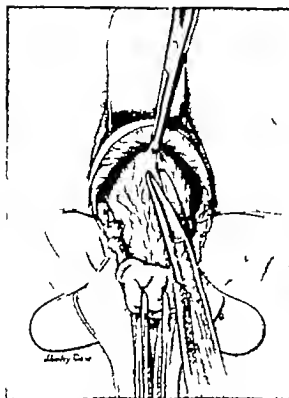


Fig. 5. Cervix pulled downward. Anterior peritoneal plica grasped with curved forceps, held up and focused transversely between uterus and clump.

be seen converging toward the uterus. These are the strong uterosacral ligaments. They are clamped and the left uterosacral ligament is ligated and cut. A full length suture of one 40 day catgut is used, the free end being left fairly long.

4. *Incision of the parametrium.* Continuing with the long suture the cervix is pulled toward the right thus exposing the base of the broad ligament. As pointed out before the left uterosacral ligament has been ligated and cut (Fig. 6). The left forefinger is inserted in the posterior cul-de-sac in order to guide the needle through the base of the broad ligament. After the suture has been tied the needle anchors this stitch to the adjoining vaginal wall. The end of the suture is secured with a curved clamp. The cervix and suture are pulled in different directions and a cut is made between. Figure 7 shows how the stitch is continued upward to ligate the left Mackenrodt ligament and the succeeding portion of parametrium.



Fig. 6. By means of the left original suture, additional looped stitches are placed in the vascular portion of broad ligament.

the suture is looped twice and kept taut by the assistant. This serves as a retractor and prevents slipping. The ligated tissues are cut away from the uterus about 1 centimeter mesial to the ligature and in a plane parallel with it. The second loop stitch is close to the uterine vessels.

The vessels are clearly identified and with the left index finger in the pouch of Douglas at the edge of the uterus which is pulled downward the needle is inserted mesial to the attachment of the bladder septum to Mackenrodt's ligament. It passes from the vesico-cervical space backward around the upper portion of the ligament and uterine vessels. Figure 7 inset, illustrates how the vessels are ligated with a square knot and the loose end of the ligature is held by a Kelly clamp. One strand of the loop is cut. The opposite side is done in the same fashion.

5. *Opening of the vesicouterine peritoneal plica.* Separation of the adnexa from the uterus

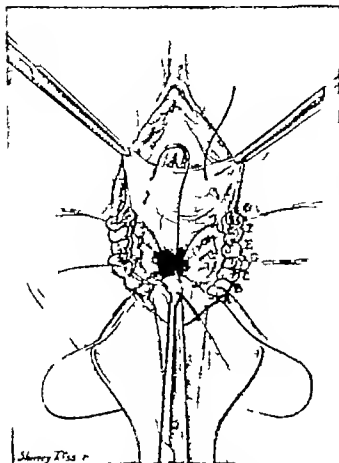


Fig. 10. Closure of peritoneal cavity with parastring suture.

The cervix is pulled downward and the anterior peritoneal plica is grasped with a curved forceps (Fig. 8) held up and incised transversely between the uterus and clamp. The opening is enlarged by cutting the peritoneum laterally. The bayonet retractor is inserted into the peritoneal cavity thus holding the bladder back.

By means of the left original suture two additional looped stitches are placed in the avascular portion of the broad ligament (Fig. 9) and the tissue is cut. Locked sutures include the tube and round ligament. The same procedure is done on the opposite side and the uterus is removed with or without the adnexa.

6 Closure of the peritoneal cavity Traction is placed on the ligatures of the adnexal stumps and the parametrial vessel bundle also the peritoneum of the bladder and rectum is pulled forward. In this manner the entire border of the peritoneum remaining after the extirpation of the uterus may be well exposed. The peritoneal cavity is now closed by a purse

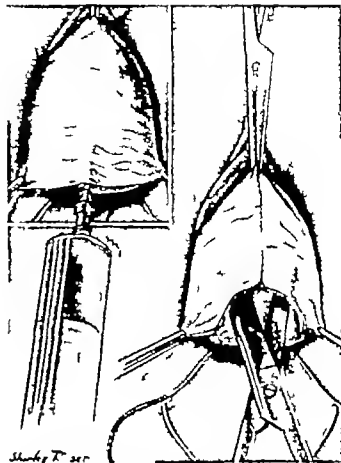


Fig. 11. Separating anterior vaginal wall from bladder by blunt scissors dissection.

string suture (Fig. 10) whereby the stumps of the following ligaments—round Mackenrodt's or cardinal broad and uterosacral—are placed extraperitoneally.

7 Care of the bladder The anterior vaginal wall is next separated from the bladder by blunt scissors dissection (Fig. 11) and suitably resected if redundant. The bladder is exposed and the plication of the bladder wall is done. The bladder fascia is then approximated (Fig. 12 inset). The needle on ligature of the stump of the round ligament is placed through the subpubic fascia near the upper angle of the wound on either side (Fig. 13). When these two ligaments are in place the bladder is pulled backward and out of the way. The round ligaments are thus interposed between the bladder and anterior vaginal wall. Interrupted sutures approximate the base of Mackenrodt's ligaments and the uterosacral ligaments. Through-and-through interrupted sutures of vaginal cuffs and stumps of the broad ligaments are seen in the inset (Fig. 13).

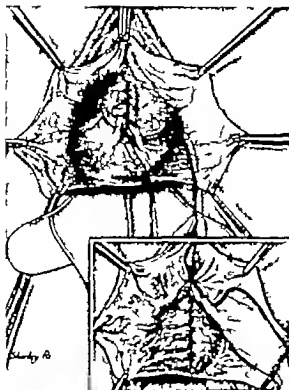


Fig. 2. Exposure of bladder approximation of bladder fascia, inset.

8 *Colporrhaphy plastic of the perineum* The posterior vaginal wall is caught with a forceps high in the vagina. The edges of the vulva are grasped with a tenaculum on each side (Fig. 14) the posterior vaginal wall is infiltrated and the mucocutaneous junction is incised with blunt scissors. The posterior vaginal wall is next incised and dissected free from the underlying fascia (Fig. 15). The fascia over the rectum is plicated the levator ani muscles are brought together in the midline with interrupted sutures, and the overlying fascia is approximated with a continuous suture (Fig. 16). Interrupted sutures of one so day catgut are used for the vaginal mucosa and black silk for the transverse mucocutaneous margins. This completes the 4 layer method of Studdiford (Fig. 17).

POSTOPERATIVE TREATMENT

A mushroom catheter is introduced into the bladder to remain 24 hours. A fracture board is placed beneath the mattress to relieve the

severe backache that invariably follows the extreme lithotomy position during the operation. As a rule one or two hypodermic injections of dilaudid are all the sedative that is required. The head rest is raised the second day after operation and a soft diet is tolerated. Light to the perineum is used twice a day for 45 minutes in order to keep the parts dry. The patient is out of bed on the 10th day.

DISCUSSION OF THE TECHNIQUE

This in general is the plan of the operation. Occasionally slight additions or alterations are needed. A narrow vaginal outlet requires a Schuchardt incision. A uterus too large to be removed in the manner described, may have to be made smaller by bisection or morcellation or the fundus may have to be luxated outward before the upper portions of the broad ligaments can be ligated.

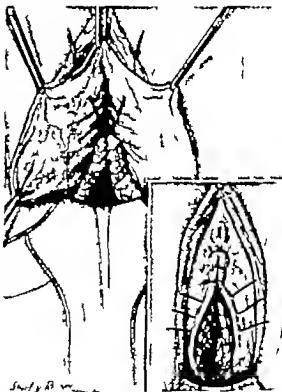


Fig. 3. Needle on ligature of stump of round ligament placed through suprapubic fascia at upper angle of round. Through and-through interrupted sutures of vaginal cuffs and stumps of broad ligaments.

However there are certain advantages in our technique that should be emphasized

1 The effect of the local anesthesia is very striking throughout the operation. Circumcision of the cervix and cutting through the parametrium is entirely painless. As the uterus follows the pull of the tenacula and direct traction is exerted on the round and infundibulopelvic ligaments some pain is experienced in a certain number of cases. Fortunately this pull is of short duration as the adnexa are quickly removed. The pain is probably due to the fact that the traction on the ligaments also involves the parietal peritoneum which is highly sensitive as we know from the fundamental work of Lennander. It is very easy at this stage of the operation to give the patient a few drops of ether or a few whiffs of gas. The remainder of the operation that is the closure of the peritoneum the interposition of the round ligaments and the approximation of the broad ligaments and the vaginal mucosa is entirely painless.

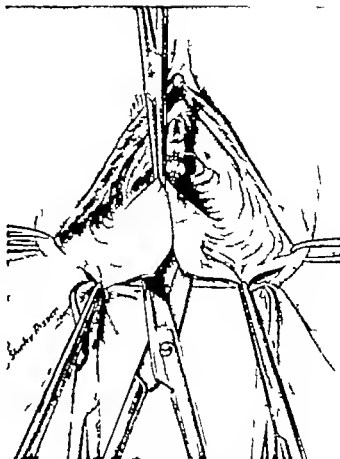


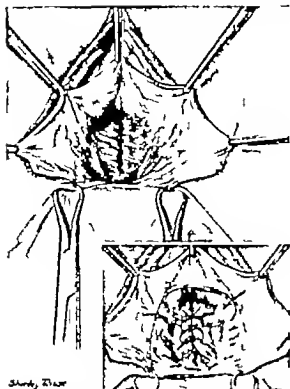
Fig. 15. Posterior vaginal wall incised and dissected free



Fig. 14. Colporrhaphy plastic of perineum

Thus under local anesthesia it entirely loses the character of a major operation there is no shock to the patient very little loss of blood if any and most important is the ease with which the tissues are identified and dissected. Systemic complications such as diabetes, cardiorenal disease, active tuberculosis which might contraindicate a general narcosis or old age and extreme obesity which render any operative intervention extremely hazardous present no objections.

2 It permits an extension of the usual indications for vaginal hysterectomy in that descent and prolapse are made at the beginning of the operation as the lateral and posterior uterine attachments are cut. In other procedures as soon as the bladder is pushed back from the cervix the anterior peritoneal fold is incised and the uterus is luxated. We feel that this has very definite disadvantages and as described in our technique the anterior cul-de-sac is not opened until the uterine vessels are cut and ligated and the posterior and lateral



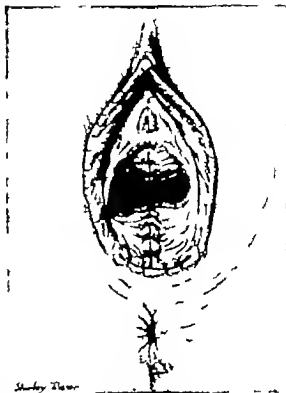
Shufly, Essex

Fig. 6. Fascia over rectum placed, levator ani muscles brought together in midline. The interrupted sutures and overlying fascia approximated with continuous suture.

attachments up to the avascular portion of the broad ligaments are cut.

3. By following the procedure of interposing the round ligaments between the bladder and anterior vaginal wall it is nearly impossible for a recurrent cystocele to take place. This is certainly a distinct advantage over other procedures in which very little attempt is made to prevent herniations of the bladder. In the Mayo technique Counsellor states that the operation "brings the stumps of the broad ligaments extraperitoneally and at the same time uses them as a supporting base for the bladder." To my mind this is the weak point of that procedure. It is anatomically unsound and a vesical prolapse between the pubic rami and upper portions of the broad ligament can occur.

4. The prevention of enterocele is accomplished by obliterating the pouch of Douglas and shortening the uterosacral ligaments. Ward noted that in marked prolapse there is



Shufly, Essex

Fig. 7. Interrupted sutures of catgut for the vaginal mucosa and black silk for transverse ischio-cutaneous margin complete the 4 layer method of Stoddard.

an extensive stretching of the uterosacral ligaments, and frequently a hernia of the posterior vaginal fornix or enterocele occurs. Many procedures fail to make any attempt to prevent these unpleasant complications.

5. Lastly by our technique a moderately deep vagina is assured. This is certainly not true following many cases of vaginal hysterectomy by other techniques particularly for genital prolapse in which one can assume that many vaginal vaults are more or less flushed with the introitus.

RESULTS

The 600 cases of vaginal hysterectomy reported in this series over a period of 14 years were private cases of Dr. George Gellhorn and myself and cases from the Barnard Free Skin and Cancer Hospital. The technique used in this series by ourselves or associates was the one here described. There was a strict follow-up of all cases in private work over a period of

TABLE I—FOLLOW UP RESULTS 1928-1942
INCLUSIVE

	Cases	Per cent
Total private cases—Follow-up of 3 years or longer	502	
Total Ward cases—Follow-up of 6 months or longer	98	
Satisfactory results	524	87.33
Recurrences		
1. Cystoceles	36	6
2. Rectoceles	28	4.6
3. Enteroceles	5	0.83
4. Incomplete vaginas	5	0.83
5. Urethrocele	1	0.33
Unsatisfactory results	76	12.66
Ward's statistics		
No data given for recurrent cystoceles and rectoceles except enteroceles following Mayo technique—		
1918-1934	82	
Enterocoele developed postoperative	15	18.4
1935-1934	40	
Enterocoele developed postoperative	4	10.0
(After improved technique of obliteration of cul-de-sac and suturing uterosacral ligaments.)		
Phaneuf statistics		
Vaginal hysterectomy for uterovaginal prolapse following Mayo technique—		
1936	56	
Recurrences	4	
(1) Enterocoeles, 1 large, 1 small	2	
(2) Enterocoele, small rectocoele some incontinence of urine	1	
(3) Small cystocoele and rectocoele	1	
Unsatisfactory results	4	7.1

The recurrences of all unsatisfactory conditions in our series is 76 or 12.66 per cent. However of this number 64 or 12.6 per cent have been cystoceles or rectoceles. We have no comparative series with which to deal. Accepting the recurrence of enterocoele upon which we have comparative statistics, we have demonstrated 5 cases or .83 per cent in our series as compared to a .8 per cent occurrence in 8 cases between 9.8 and 1934 or an occurrence of 4 cases or .4 per cent after modification and perfection of the technique. I believe that we are justified in the conclusions arrived at from this statistical basis that the tendency is at least ten times greater for occurrence of an enterocoele following the Mayo technique with the Ward modification over our method.

3 years or longer and from the clinic over a period of 6 months or longer. Our results with those of Ward and Phaneuf are summarized in Table I.

CONCLUSIONS

The literature dealing with vaginal hysterectomy with possibly one exception has demonstrated the lack of follow up information and almost complete absence of statistics upon which to base logical conclusions as to the efficiency of a procedure.

The details of our operation are described and depicted in this paper. This is to justify the assumption that our technique is the one of choice not only through the ease of accomplishment but likewise the lack of recurrence of undesirable sequelae. The number of cases is of sufficient magnitude to warrant a basic supposition of reliability in our statistics.

It is with confidence that a greater interest in this procedure will be shown by a betterment of these statistics.

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SURGICAL EXPERIENCES WITH ABDOMINAL WOUNDS IN THE NORTH AFRICAN CAMPAIGN

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BATTLE casualties from abdominal wounds have always had a rather high mortality. In World War I the majority died in the field (4) although considerable progress had been made in their management by the end of the war. However Rippey reports that even in civilian life there is a mortality of 55 to 60 per cent in individuals under 40 years of age. The lowest single yearly figure was 41.3 per cent. Hamilton and Duncan have likewise reported a 51 per cent mortality for gunshot wounds of the abdomen.

In modern warfare Gordon Taylor (5, 6) reported 50 per cent recoveries for abdominal injuries but with mortality variations from 40 to 80 per cent when various viscera were involved. The Germans have reported a 66 per cent mortality (10) and Ascroft has reported a 37.5 per cent postoperative death rate for abdominal wounds treated in one of the British mobile surgical units. In the Spanish war there was almost a 100 per cent fatality in patients with wounds of the colon (3).

The authors have happily found in their experience that with the full employment of the various newer therapeutic measures now available both before and after operation the mortality figures for the abdominally wounded from the American Army in North Africa did not approach the figures quoted here. Ample credit must be given also to the efficient medical evacuation rendering surgery available without undue delay. The over-all mortality of all cases seen by the authors, both operable and inoperable, is moribund has been 20.41 per cent. Postoperative mortality for those operated on in one evacuation hospital was 11.94 per cent. No patients were transported after operation until their condition warranted and none died therefrom en route to the rear through supporting larger evacuation hospitals. It is granted a certain ultimate additional mortality may accrue due

to late complications and secondary surgical procedures, as closures of colostomies.

SOURCE OF ADMISSIONS

The hospital in which the patients were treated whose records are herein reviewed entered the African Campaign with the invasion forces as a surgical hospital. Although later reorganized after the Southern Tunisian campaign as a semi-mobile evacuation hospital it functioned throughout the Tunisian Campaign from early January to the close of the Campaign in May in a forward position. Usually located from 7 to 35 miles behind the actual front lines, the distance varying with tactical considerations its employment was such that a good cross-section of the type of abdominal casualties that may be expected in modern military campaigns was thus obtained.

No attempt will be made here to explain the system of Army evacuation. However it should be noted at this time that en route to our hospital, besides routine morphine administration many of the injured had received amounts of blood plasma intravenously varying from 250 to 1,000 cubic centimeters, depending upon their degree of shock. This undoubtedly allowed many patients to be transported to the hospital who otherwise might well have died en route or developed such severe shock that the condition was irreversible on admission. A certain small group of patients included in the present series had undergone emergency surgical operations in the clearing stations forward of this hospital. On occasion perhaps as the result of a change in tactical situation these patients were transported to us at an early postoperative date. Admitted at times still under anesthesia at times in severe irreversible shock, their progress was not infrequently one of rapid decline and fatality despite the utmost of supportive

measures. As will be shown postoperative patients who have recently undergone celiotomy do not tolerate early transportation.

CLASSIFICATIONS OF ADMISSIONS

There were 98 patients with penetrating abdominal wounds admitted to this hospital during the campaign. The incidence was a good deal lower than was expected. A comprehensive study of patients with chest injuries admitted to this hospital was made and the incidence of the abdominal wounds and chest wounds was practically identical.

Three types of abdominal cases admitted to this hospital will be considered in this paper. Those who were operated on in this hospital, those on whom surgery had been done at a forward medical installation, usually by clearing station personnel or an attached auxiliary surgical team, and lastly those who were treated conservatively without surgery.

CAUSATIVE MISSILE

The causative missile in abdominal wounds has a direct bearing on the mortality rate and type of wound but little influence on the treatment. The causative agents encountered were missiles from small arms fire including strafing from the air, fragments from high explosive shells and bombs or land mine fragments. There was not one bayonet wound of the abdomen in this series.

Bullets from small arms fire in most instances caused a penetrating wound of the abdominal wall, sometimes a through and through wound with a perforating type of intra-abdominal injury. With this type of abdominal wound associated extra-abdominal wounds were unusual.

High explosive shells, bombs or land mine fragments caused both penetrating and perforating (through and through) wounds of the abdomen and in addition in some cases marked destruction of abdominal parietes. The type of intra-abdominal injury was usually unpredictable. It might be a simple perforation of the viscus, multiple perforations or almost complete mutilation and destruction of the involved organ or organs.

Associated injury in addition to that produced by the explosive fragments might be

caused by concomitant blast. In a few instances clothing or some other foreign body was also carried in by the initial missile. Many patients wounded by shell bomb or mine fragments had other serious wounds incurred simultaneously which with the abdominal wound markedly influenced the prognosis, morbidity and mortality. Whereas in civil life a traumatic intra-abdominal wound is usually the only problem for the surgeon to deal with in war casualties associated injuries in addition to the abdominal wound are the rule rather than the exception.

FACTORS INFLUENCING MANAGEMENT

A. Time interval. One of the first and primary considerations in a discussion of the treatment of abdominal wounds is the time element involved from injury to time of operation. Everyone is familiar with the surgical dicta laying down the relationship of increased mortality with delayed time intervals before operation in acute traumatic intra-abdominal conditions. We feel that in view of our experience although the importance of the time element cannot be refuted, some revision of thought in regard to this matter must be considered. The average time from injury to operation in this hospital was roughly 18 hours, approximately three times the usually accepted safe interval prior to operation. We say roughly because in some cases it was impossible to find out the exact time of injury but it was known to be within 24 hours. In computing this average however these cases were calculated as an interval of 24 hours. The extremes of the series were 1 hour for the earliest and 56 hours for the latest.

B. Condition of patient on admission. The condition of the patient on admission was the index to surgical treatment not only of those with abdominal wounds but of all wounded admitted to this hospital. Under this index was included the length of time elapsed since the injury, if obtainable, degree of shock, presence or absence of continued internal hemorrhage, magnitude and condition of wound or wounds, and general mental and physical condition of the patient. Of these in the majority of cases we feel that accurate determination of the degree of blood loss and shock and ade-

quate treatment of these has a more important bearing on the outcome of the case than any other factor in treatment. It must also be remembered that many of these patients had been exposed to enemy action continuously for long periods of time, sometimes without adequate water, food or rest. Thus their general mental and physical condition was definitely subnormal. Their youth and general good physical condition as a result of military training were factors of definite advantage to both the patient and the surgeon.

SURGICAL MANAGEMENT

Preoperative management. Before operation all patients with abdominal wounds were treated in the shock wards. Patients to be treated conservatively without surgery or on whom surgery had been done elsewhere were also admitted to the shock wards and received their initial treatment there.

The most important factor in preoperative management was the accurate estimation of the degree of shock, amount of blood loss and presence of continued bleeding. All patients with abdominal wounds were suffering from some degree of shock, from slight to irreversible, and needed prompt and adequate treatment for the same. In most of the patients with abdominal wounds, shock was the result of the trauma of injury and associated blood loss. Perusal of the literature often gives one the impression that plasma affords complete replacement therapy. The degree of blood loss does not seem to have been generally appreciated. Only by its replacement with blood can these patients be properly prepared. Repeated instances have occurred in which large quantities, 1000 to 2000 cubic centimeters of plasma have been given to patients while awaiting procurement of blood and effective response to treatment was not obtained until after the blood transfusion had been given at times in amounts of 1000 cubic centimeters or more. Furthermore those patients receiving blood seemed to withstand the necessary reparative surgery much better than those receiving only plasma before, during and after operation. Hamilton and Duncan state that hemorrhage more often than peritonitis was the cause of death in their series of cases.

The first consideration in preoperative treatment was the arrest of any visible hemorrhage, often the result of an associated wound. To accomplish this, tourniquets, pressure dressings, and occasionally hemostats were applied promptly. The administration of plasma intravenously was then begun immediately while at the same time a specimen of blood for cross-matching was obtained. The wounded soldier's blood type was indicated on his identification tag. Only in the most dire emergencies was blood from a universal donor given without cross-matching. In 374 transfusions, 5 reactions were noted and none of these was fatal as they were of a pyrogenic rather than a hemolytic type.

Until the increasing number of transfusions required made it impossible the blood was obtained from the personnel of this hospital. Then a living blood bank composed of service troops was established. A proportionate number of each of the four types was brought to this hospital daily and they were available 24 hours a day, as soon as they had been used as donors they were returned to their respective commands. In most cases it was possible to have a transfusion of whole blood set up and blood running in the patient's vein in 45 to 60 minutes in dire emergencies, without cross matching less than 30 minutes. Following the southern Tunisian campaign a kerosene burning refrigerator was obtained and a blood bank of refrigerated blood was maintained. This bank made possible the constant availability of blood of known type for immediate cross matching when needed. The total elapsed time between admission of the patient and his reception of the transfusion was thereby markedly reduced, usually to 30 minutes, the time necessary for the cross match itself.

The amount of plasma and blood used varied; some patients needing only 250 cubic centimeters of plasma to prepare them for operation. In others, as high as 2500 cubic centimeters of plasma and the same amount of blood over a period of 24 to 36 hours would be given. In explanation of this statement, those large amounts would be given before operation during the surgical procedure and in the immediate postoperative period. We have never experienced the untoward toxic

reactions from large volume transfusions with citrated blood in patients with massive hemorrhage, as has been suggested by Ivy and associates. Contrary to the belief of some writers in current literature that plasma alone is satisfactory in the treatment of shock associated with hemorrhage we believe from our experience that nothing takes the place of whole blood. This opinion is based not only on this small series of abdominal cases but also upon observation of the large number of other casualties of a major nature admitted to this hospital. Enough blood and plasma must be given to stabilize the circulation by complete restoration of the circulating blood volume before surgery is attempted. Each case is an individual problem and no dogmatic rule can be laid down as to the amount to be given. During the period when the patient was getting plasma blood or both an attempt was made to keep the patient warm and quiet so he could get as much rest as possible. If morphine was indicated it was given. However it is surprising how many of these men when put to bed warmed with hot water bottles and blankets dropped off to sleep without any sedation. If indicated oxygen was administered with a BLB¹ mask at 4 to 6 liters per minute. Occasionally 5 per cent glucose in saline was given intravenously in an effort to convert what appeared to be a marked imbalance of the electrolytes as the result of dehydration. If this treatment outlined did not stabilize the patient's circulation no attempt was made to perform any surgery unless it was felt the patient had active internal bleeding. In that case with both blood and plasma running in two different veins surgery would be undertaken with the idea primarily of stopping the hemorrhage. Otherwise we felt that the patient was in irreversible shock and attempts at surgery would be futile. In most cases of this type the magnitude of the wounds precluded any possibility of life. However the maximum attempt was always made to improve the patient's condition to the point at which surgery was justifiable without absolutely assured mortality. It is for the reasons listed that we say the condition of the patient

¹Boothby Lovelace and Bailett.

is more important than the time element in the majority of the wounded in determining the time of operation and successful outcome of the case.

Operative management. It would be impossible to describe the surgery involved in each individual case. However we believe that certain features in technique and some of our observations may be of value to those soon to be exposed for the first time to this type of surgery.

A tabulation of viscera involved and the type of wound is shown in Table I. The table shows that in most cases several intra abdominal viscera have been injured. The incidence of associated extra abdominal injury and the region involved is noted in Table II. In both tables statistics are given for patients operated on after admission as well as those operated prior to admission.

Perusal of the tables will also further indicate that not only are 2, 3 or 4 different organs frequently involved in the injury but when the small bowel is involved multiple perforations occur about ten times as often as single perforations. In some cases as many as sixteen perforations of the small bowel were encountered. Involvement of diaphragm the liver or spleen with perforation of small or large bowel or both was also not uncommon.

Although the majority of patients came to operation in relatively good condition some were in precarious condition and did not respond to intensive measures to stabilize the circulation and in them it was our opinion that active internal bleeding was present. Although the speed of an operating surgeon is not usually considered the essential criterion in any operative procedure in these cases it was very important. For that reason it has been our policy to do the simplest and most easily performed procedures compatible with saving the patient's life even though this might necessitate further surgery at some future date. Even following this policy many of the operative procedures were exceedingly long because of the magnitude of the injury. It has been most revealing to see the tremendous amount of injury and associated operative repair a previously healthy young adult will tolerate and survive. How a missile can

TABLE I—TABULATION OF VISCERA INVOLVED AND TYPE OF WOUND

Viscera involved	Type of wound	Patients operated upon after admission			Patients operated upon prior to admission		
		Me	Je	St	Co	Ca	Re
Diaphragm				3			
	Perforation						
	Laceration						
Stomach							
	Perforation						
	Laceration						
Small intestine				11			
	Single perforation						
Duodenum							
Jejunum							
Ileum							
	Multiple perforations	20					
Duodenum		10					
Jejunum							
Ileum		8			5		
	Lacerations	6					
Duodenum							
Jejunum							
Ileum							
Cecum							
	Single perforation					2	
Ascending							
Transverse							
Descending							
	Multiple perforations						
Ascending							
Transverse							
Descending		3					
	Lacerations						
Ascending							
Transverse							
Descending		5					
Sigmoid							
	Lacerations						
Rectum							
	7						
Intra-abdominal	Perforation						
	Laceration						
Extraperitoneal	Perforation						
	Laceration						

TABLE L—TABULATION OF VISCERA INVOLVED AND TYPE OF WOUND—Continued

Viscera involved	Type of wound	Patients operated upon after admission			Patients operated upon prior to admission		
		Me	Je	St	Co	Ca	Re
Mesentery							
	Perforation						
	Laceration		3				
	Hemostasis						
Liver				10			3
	Perforation						
	Laceration	6					
Spleen				11			
	Perforation						
	Laceration						
Biliary tract				3			
Gall bladder	Laceration						
Common Duct							
Hepatic Duct	Small perforation						
Pancreas	Small course						
Genitourinary				3			
Kidney							
Ureter							
Bladder				3			
Intra-abdominal	Perforation						
	Laceration	3					
Extraperitoneal (including ureters)	Perforation						
	Laceration	7					
Extraperitoneal space	Hemostasis			3			
Total injuries to viscera				21			27

SUMMARY

	Patients operated upon after admission	Patients operated upon prior to admission
Patients with penetrating abdominal wounds in whom it was felt exploration was made very late so late abdominal injury was found	8	
Total number of cases in whom there was injury of intra-abdominal viscera	29	16
Average number of viscera involved per case (in 45)	6.3	6.6
Mortality in	24	11

pass entirely through the abdominal cavity without injury to any intra abdominal structure is another matter of interest. This fact explains the exploratory procedures done because of abdominal wounds requiring investigation in whom no intra abdominal injury was found (Table I).

The first consideration in operative management is elementary in surgery—adequate exposure. The previous notation by fluoroscopy of the location of foreign bodies when lined up with the point of entrance gave some idea of the region of the abdomen traversed by the missile or missiles and the incision was planned accordingly. We have usually used a long rectus or paramedian incision depending upon the side we felt the intra abdominal injury pre-dominated. If uncertain a midline incision going either to right or left of umbilicus may be enlarged to cope with any situation that may be encountered. Sometimes because of damage to abdominal parietes the site of incision is precluded. When the abdomen was opened our first concern has been the control of any active bleeding if present usually from the spleen liver or mesentery. In cases with a great deal of intraabdominal bleeding a suction apparatus is invaluable. The amount of bleeding from apparently trivial injuries of the mesentery or a few perforations of the small intestine can be tremendous and out of all proportion to the injury that is found.

After any active bleeding is controlled the next step has been a systematic examination of the abdominal viscera. We have examined colon first closing temporarily any perforations by Allis clamps to avoid any further contamination of the abdomen if perforation was present. One must be careful not to overlook extraperitoneal injuries of the large bowel. Examination of small bowel beginning at the ligament of Treitz or the cecum was done next, care being taken to discover any possible injury of the mesentery. Other intra-abdominal viscera were then systematically examined.

In most severe liver injuries suture will be impossible. Muscle grafts and a pack have controlled hemorrhage from severe liver injuries very well in our experience. Suture

TABLE II—INCIDENCE OF ASSOCIATED EXTRA ABDOMINAL INJURY AND REGION INVOLVED

Region involved	Patients operated upon after admission	Patients operated upon prior to admission
Head		
Chest		
Back	3	
Upper extremity	7	
Lower extremity		
Total incidence associated injury	43	
Total cases	67	6
Percent of cases with associated injury	67.3	90

may be done in injuries of lesser degree. For this we have used heavy chromic catgut. These cases were all drained (except one early case) using either the end of the liver pack or separately by Penrose drains. Drainage was done to establish a tract for drainage of blood bile or any dead liver tissue that might sequester at a later date. It may be and is usually advisable to give small dose of sodium pentothal when the pack is later removed. We have found one case of secondary complete mechanical intestinal obstruction the result we felt of reaction to a liver pack that had been left in too long. For that reason we believe that we should start to remove the drains in 3 to 5 days.

If the injury to the spleen was of a minor nature as a crease on the surface or a small laceration in a border with no bleeding present nothing was done. If the splenic wound was of a major nature splenectomy was done and no attempt made to pack or suture the organ.

Minor perforating and lacerating wounds of the stomach were closed by two layers of inverting sutures in most instances without trimming away any everted gastric mucosa. In major lacerating injuries some revision of the wound or partial gastric resection was sometimes necessary to effect a tight and anatomical closure. This was also done with two layers of inverting sutures. Connell, Lembert or Cushing sutures may be used as desired. Both catgut and silk were used silk on the outer layers preferably because no

catgut sutures with atraumatic needles were available and it was our opinion that less trauma was produced by the use of silk.

The small intestine was the most commonly and usually the most extensively involved of the intra abdominal viscera. Injury ranged from a single perforation to almost complete mutilation of a segment of gut. The repair of injuries to small bowel had an important bearing on the length of the operative procedure. In some cases in which patients were in very poor condition with a tremendous amount of damage closure of minor perforations and lacerations was done with one row of suture inverting *serosa to serosa*. Although this is not recommended as a routine procedure in dire emergencies it has been used successfully. Routine closure was by two layers of inverting suture in the transverse axis of bowel the everted mucosa was not trimmed away. Resection was done when the blood supply was damaged either by injury to the mesentery or by separation of the mesentery for any distance greater than 2 inches when there was a complete mutilation of a segment of bowel or when multiple perforations were so placed that their repair would constrict the lumen of that segment of bowel. Both end-to-end and side-to-side anastomoses were used in resections and in repair of transections of intestine. It is not within the realm of this paper to discuss the merits of these two types of anastomoses. Both have given satisfactory results in our hands but an end-to-end anastomosis was used more frequently because it could be completed in a shorter interval of time.

Most lesions of the colon were exteriorized. This was done for two reasons: first, it was the simplest and least time consuming thing to do in most cases, especially when injury to other viscera necessitated a long operative procedure and, second these patients had had no preparation for colon surgery and unless the lesion was very minimal and the bowel empty it was a safer procedure than primary suture or resection and anastomosis. If resection had to be done a Rankin obstructive type or a modified Mikulicz procedure was used. Occasionally a colon perforation or laceration was sutured primarily. Suture

would also be done if there was already a colostomy for an associated injury proximal to that particular lesion. Colostomy was done for extraperitoneal perforation of the rectum.

Rents or lacerations of the diaphragm were closed routinely with interrupted mattress silk sutures closure being in the direction of the fibers with overlapping of the edges.

We have deemed it inadvisable to try to control retroperitoneal hemorrhage as in our experience it has always been self limited. Neither have we deemed it advisable to explore the retroperitoneal space for a known foreign body in the presence of a retroperitoneal hematoma. Our results would seem to indicate that our surmise has been correct.

Intraperitoneal lesions of the bladder were repaired with two layers of inverting sutures. If there was a perforation or a small laceration, an indwelling urethral catheter was used. If a large laceration a suprapubic cystostomy was done. A suprapubic cystostomy was also done for extraperitoneal lesions of the bladder or injuries of the urethra in which it was completely severed or impossible to pass a urethral catheter.

Sulfanilamide powder (10 to 15 grams) was placed in the peritoneal cavity in all exploratory celotomies. Drainage was employed only in wounds of the biliary tract urinary tract, and colon. All other incisions were closed tightly. In some cases of gross contamination from injuries of the colon only the peritoneum was closed initially and secondary closure of the remaining layers was done at a later date when the wound was clean.

The anesthesia of choice in most cases was nitrous oxide—either by closed absorption technique or drop ether. Not infrequently an intratracheal tube was used. Rarely in patients in exceptionally good condition spinal anesthesia was employed. The agents most commonly used were 1:5 cubic centimeters of nupercaine 1:200 dilution and 100 to 150 milligrams of procaine.

In most cases the administration of plasma or blood has been continued throughout the surgical procedure.

Postoperative management. Postoperatively most patients with abdominal wounds were

returned to the shock ward and further treatment was given to prevent if possible any postoperative shock. Oxygen constant gastric suction and intravenous sodium sulfathiazole or sodium sulfadiazine were used routinely 5 grams being given initially and followed by 2 5 grams every 6 to 8 hours. Fluid balance was closely checked 1000 cubic centimeters of normal saline 2000 cubic centimeters of 5 per cent glucose in distilled water and 500 cubic centimeters of plasma being given daily to meet the basic electrolytic and protein requirements. Additional 5 per cent glucose in normal saline was given to equal the amount of drainage by the gastric suction. In some cases this would bring the total fluid requirement to 10 to 12 liters a day. Only one patient developed an edema. A urinary output of at least 1000 cubic centimeters in 24 hours was maintained. In absence of adequate laboratory facilities for accurate studies in blood chemistry, we felt this rule of thumb worked very well. Adequate amounts of intravenous vitamins B and C were administered with the parenteral fluids each day. Usually in 4 to 5 days sufficient peristalsis associated with the passage of flatus was present to permit the removal of the nasal tube. Patients then began the usual liquid diet for surgical patients of this type. Blood transfusions were given as indicated. Careful check was kept on all blood counts and urine to detect at once any deleterious effect from the intravenous sulfonamides. In 7 to 10 days most patients were transportable in good enough condition so that except in a very few instances they were again evacuated to the rear from the large evacuation hospital to which we had sent them. There were no deaths during or as the result of transportation in any of this group treated and held until we felt they were fully transportable on the way to or at any evacuation hospital. No deaths were reported during the latter phase of evacuation.

ANALYSIS OF RESULTS

In this series of 67 patients operated on and cared for in this hospital until fully transportable there were 8 deaths a mortality rate of 11.94 per cent.

A brief résumé of these fatal cases follows

CASE 10. An invasion casualty who had extensive wounds of the urinary bladder and posterior urethra died 7 weeks after operation of a series of complications resulting from a small low sigmoid perforation. Additional unfortunate circumstances influencing the patient's course cannot be given in detail.

CASE 21. Patient with a left-sided thoracoabdominal wound had had the external chest wound superficially sutured prior to admission. Due to severe laceration of the stomach and diaphragm the patient had developed an internal sucking wound of the chest. (This case is being reported in more detail by one of us [JMS] with another member of the hospital staff in a series of 107 thoracic cases.) Operative closure of the diaphragm allowed development of a tension pneumothorax which blew out the external wound at the close of the abdominal operation and the patient died from the shock of recurrent severe changes in the intrathoracic pressures superimposed upon an already severe injury.

CASE 25. Patient had multiple extremity wounds and complete destruction of the blood supply to the small bowel at the root of the mesentery with gangrene operative fatality.

CASE 40. Splenectomy was done for a shattered bleeding spleen, anastomosis following resection of destroyed portion of jejunum and Rankin obstructive resection of badly damaged transverse colon. Death occurred 16 hours after operation despite a transfusion of 3000 cubic centimeters of whole blood.

CASE 47. Severe blast lacerations (2) of the stomach and multiple shrapnel perforations of the small bowel. All repaired but patient died 12 hours after operation in shock despite transfusion of 1500 cubic centimeters of whole blood.

CASE 49. Severe intra-abdominal hemorrhage from splenic vein which had been severed by a shell fragment behind the junction of the middle and distal third of the pancreas with death before hemorrhage could be controlled.

CASE 51. Debilitation of multiple, severe shell fragment wounds of all extremities, packing of severe lacerations of liver and repair of stomach laceration. Patient died 24 hours after operation of sudden severe, secondary shock.

CASE 66. Multiple severe shell fragment wounds of left side of the body including compound fractures of the left humerus and left femur, multiple small bowel perforations (ileum) and lacerated transverse colon. Patient died suddenly following convulsive seizure during anesthesia.

IMMEDIATE POSTOPERATIVE COMPLICATIONS

The incidence of postoperative complications in the same group was remarkably low considering the magnitude of most of the wounds and surgical procedures necessary for their repair.

lower abdomen with loss of tissue of abdominal parietes evisceration and multiple perforations of the small intestine were visible and there were severe penetrating wounds with compound fractures of the left forearm, right arm, left thigh and leg. The patient was in irreversible shock and in spite of 1000 cubic centimeters of whole citrated blood and 750 cubic centimeters of plasma he died shortly less than 4 hours after admission. The extent of his injuries precluded any possibility of life and any attempted surgery would only have resulted in a death on the table.

SUMMARY

1 A series of 98 cases of abdominal war wounds with 20 deaths, an overall mortality of 20.41 per cent is presented

2 In 67 of the patients who were operated on and treated in this hospital until they were fully transportable a mortality of 8 or 11.94 per cent is reported

In 16 patients operated upon previous to admission to this hospital and cared for here until transportable a mortality of 5 or 31.25 per cent is known. This would seem to indicate that postoperative abdominal cases do not tolerate early transportation

3 In restoration of circulating blood volume in cases of shock due to trauma of injury and blood loss plasma alone is not sufficient citrated whole blood transfusions must be used in a high proportion of cases. The amount of blood loss may be easily underestimated

4 No toxic reactions from large volume citrated blood transfusions were noted

5 Involvement of multiple intra-abdominal viscera should be expected in penetrating abdominal war wounds and at operation complete and careful exploration should be done to avoid overlooking some remote injury

6 Associated extra-abdominal injury with the abdominal war wound is the rule rather than the exception

7 The average time which elapsed between the time of injury and operation was 18 hours

The relatively low mortality (11.94 per cent) in this group as the result of modern preoperative and postoperative therapeutic measures would seem to warrant some revision of thought regarding the duration of the safe interval of operability from the time of injury to operation. This interval as has so often been stated should not exceed 6 hours.

8 The condition of the patient on admission to the hospital is, in our experience the most important index of the type of treatment which should be carried out.

9 In spite of the evident abdominal wound conservative rather than operative treatment is sometimes indicated by the duration location and severity of the wound and the signs and symptoms present

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VAGOTOMY IN THE THERAPY OF PEPTIC ULCER

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RECENT years have seen increasing emphasis placed upon the rôle of psychic factors in peptic ulcer. Whether this rôle is a dominant or a subordinate one is not clear and its importance may vary in individual cases but that it is usually present to some extent is widely accepted today. Despite this, the procedure of choice for those cases which do not respond to a medical regimen is subtotal gastrectomy—an extremely radical surgical procedure associated with a varying percentage of unsatisfactory results. The rationale of this procedure is to diminish or abolish the acid secretion and to remove, if possible the ulcer bearing area. This obviously does not get at the basic etiological mechanism but merely breaks into and interrupts a vicious cycle set up by more remote causes. Surgical procedures, similarly directed toward a single facet of a much broader problem are used extensively in the treatment of Graves disease, hypertension and ulcerative colitis although in each of these a more rational approach is the ultimate desideratum.

Since the psychic factors in the genesis or perpetuation of peptic ulcer (i.e. those having to do with the psychic phase of gastric secretion and with motility) are mediated through the vagus, it would seem logical to attempt to interrupt these influences by section of the gastric branches of this nerve. A few reports in which this procedure was employed are to be found in the literature but these deal in great part with the application of vagus section to neurogenic gastric disorders, such as gastric crisis in tabes dorsalis. In 1912 Exner and Schwartzman reported 20 cases in which they had performed subdiaphragmatic anterior vagotomy for gastric crises in tabes (Fig. 1). Ten of their patients were cured and 2 were improved there was 1 operative death. Latarjet devised a more extensive operation in an effort to achieve complete division of the vagus supply to the stomach (Fig. 1). The aim of this procedure

was to cut off sensation, diminish the frequency and intensity of the contractions, and probably to diminish acidity. Twenty five patients were operated upon and good results were obtained in those suffering from gastric crises without organic disease of the stomach or duodenum. Bircher, Schiassi and Stierlin also devised surgical techniques for vagotomy (Fig. 1) and reported good results in the treatment of peptic ulcer. In 1937 Barron and Curtis reported a case of gastric hypertonism in which an anterior vagotomy was done. They observed a marked decrease in the periods of gastric motility the effect lasting for at least 5 months after operation. Winkelstein and Berg in 1938 advocated an anterior gastrectomy for gastric vagotomy plus a subtotal gastrectomy for the surgical treatment of duodenal ulcer accompanied by high gastric acidity. They reported 34 cases of which 26 developed achlorhydria 16 immediately and 10 later on. Their method of vagotomy is similar to that of Exner or step A of Latarjet a procedure in Figure 1.

With the possible exception of Latarjet all of the forementioned authors employed partial rather than total vagotomy. This may have been done for one of several reasons: the belief that partial vagus section would accomplish the objective or the opinion that total division constituted too difficult a surgical feat or the fear of possible harmful physiological effects upon the organism of complete vagus section. However a considerable volume of experimental data has been published on the effect of section of the vagus upon gastric secretion and motility. It may be of value to review briefly some of these findings.

McCrea and his associates (11-12) reviewed the subject comprehensively up to 1925. Their conclusions were as follows. The motor activity of the stomach is unaffected by unilateral vagotomy and save for a decrease in the initial emptying time it is not markedly influenced by double vagotomy. Section of the vagi eliminates the psychic secretion but an active gastric juice is still secreted because of the chemical phases. Hartlet in 1929 following intrathoracic vagotomies on dogs, reported that complete vagotomies induced a decrease in acid secretion but if the vagotomy were incomplete no such result was

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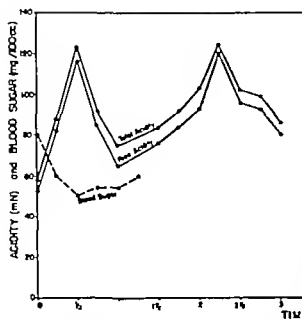


Fig. 3. Acidity and blood sugar curves for insulin test before (left) and after (right, supraesophageal)

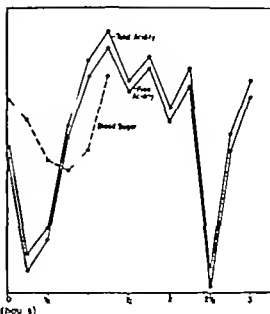


Fig. 4. Acidity and blood sugar curves for insulin test before (left) and after (right, supraesophageal)

jejunal ulcer. The hemoglobin was 35 per cent, but blood cell count 0.500, the normal differential. A Rebt test meal revealed total acidity up to 85, free to 65. Milk drip therapy was instituted. The patient improved and was discharged. In follow-up x-ray examination on October 23, 1934, jejunal ulceration as no longer visible.

Fourth admission, 21 Feb. 9, 1935. Severe epigastric pain occurred 3 weeks prior to this admission. Gastrointestinal series and gastroscopy both revealed the presence of jejunal ulceration. Some relief obtained. Medical therapy and the patient was discharged.

Fifth admission, November 8, 1935. Readmission necessitated by the recurrence of severe persistent epigastric pain. It was felt that the patient presented an unusually severe ulcer diathesis and that some alternative to the inadequate medical therapy was required. It was decided to attempt the elimination of central nervous system influences by complete vagotomy and accordingly transpleural supraesophageal vagotomy as performed under vertebrobasilar anesthesia. A portion of the 8th left rib was resected, and the 6th and 7th were divided near their angles. The pleura was opened and the esophagus was exposed. A large left vagus trunk and smaller right vagus nerves were divided. The postoperative course was complicated by large pleural effusion from which the patient recovered. During the hospital stay epigastric pain was absent, but it recurred on the day of discharge.

Test meals—7th admission	Maximum acidity (free/total)	
	Before operation	After operation
Alkaloid	95/105	70/100
Lambon (see Fig. 3)	70/125	70/100
Insulin	—	100/105
Night secretion	85/100	75/100

Sixth admission, October 30, 1936. The patient was treated for an empyema. The site of the thoracic operation by incision and drainage but there were no gastrointestinal complaints.

Seventh admission, November 3, 1937. Ten months before this admission there had been an episode of melena, and severe epigastric pain recurred 3 months before. A gastrointestinal series again revealed the presence of jejunal ulcer and an insulin test meal showed a total acid response up to 135, free acid to 115. The pain was so severe that the patient, during a subsequent operation. Surgical exploration revealed jejunal ulcer. The duodenum, which at the time of the first operation had been hard and indurated, now found to be soft and free of all evidence of an inflammatory process. A portion of the jejunum and an additional portion of the stomach (about 4 inches) were resected, the line of gastric resection being brought justacardiopharyngeal. An antecolic terminolateral gastrojejunostomy and jejunojejunostomy were then performed. The postoperative course was relatively smooth. Although its values were lower postoperatively insulin test still revealed acid response with maximum total and free acidities of 55 and 35 respectively.

This case is of extreme interest from two standpoints. First, although it was believed that complete gastric vagotomy had been performed, the postoperative response to insulin indicated that this was not the case. Anatomic evidence regarding the validity of the insulin test in this respect is given below (see Case 2, Fig. 4). Technically therefore, it appears extremely difficult to produce a complete vagotomy, even with the unusually good exposure afforded by a transpleural approach. Second partial vagotomy seems in-

effective in reducing the gastric secretory response to alcohol or to insulin and the procedure had very little therapeutic effect.

CASE 2 L. U. (M.S.H. No. 448647) First admission February 25, 1937. This patient was a 38 year old male who had had a subtotal gastrectomy for duodenal ulcer 12 years before. For the past 2 years he had been having epigastric pain and melena. The patient was quite thin, but otherwise physical examination was negative. A gastrointestinal series revealed a gastrojejunal ulcer. He underwent medical therapy.

Second admission, March 4, 1939. Readmitted for ulcer pain and renal calculi. Treated medically with improvement.

Third admission, June 29, 1939. Left nephrectomy for calculus pyonephrosis.

Fourth admission November 13, 1939. Patient complained of intractable epigastric pain. Physical examination revealed marked emaciation. Epigastric tenderness was present but the examination was otherwise essentially negative. The hemoglobin was 70 per cent. The urine was normal. The blood urea was 17 milligrams per cent. X ray examination revealed a small gastric pouch and a jejunal ulcer.

Test meal—before operation

Maximum acidity (free/total)

Alcohol	65/70
Insulin	43/48
Night	76/82

Since only a very small portion of the stomach remained, additional resection would necessitate a total gastrectomy with its attendant high mortality. On the other hand a bilateral vagotomy might materially reduce the persistent acid and thus bring the desired therapeutic result. Accordingly a (presumably) complete vagotomy was performed through the transpleural supradaphragmatic route, under avertin-ethylene anesthesia. The postoperative course was complicated by the development of a left hemopneumothorax and a right lower lobe bronchopneumonia. The patient then improved gradually until the 14th day after operation when improved roentgenography showed a small atelectasis of the right lower lobe pneumonia and a small residual loculation of air in the left chest. On the 14th day resolution of the right lower lobe pneumonia and a small residual loculation of air in the left chest. On the 14th day resolution of the patient suddenly became extremely cyanotic and death ensued rapidly. Postmortem examination revealed a massive hemorrhage into the right adrenal and an atrophic left adrenal (previous nephrectomy). The other findings were a small encapsulated pyema, a jejunal ulcer and a right renal calculus. Dissection of the hemorrhage into the right adrenal demonstrated that several innominate and gastric vagi still remained (see Fig. 4), despite the surgeon's belief that all the vagus branches had been divided. It was estimated that 60 to 80 per cent of the vagal nerve fibers had been interrupted leaving sufficient to mediate a significant degree of gastric acidity according to our experimental work previously reported.

A careful and determined effort was made to sever all the vagus fibers descending to the stomach, through a transpleural supradaphragmatic approach, through the lower esophagus. The technical difficulty of achieving this objective is indicated by the postmortem dissection at which 20 to 40 per cent of the fibers were found to be intact. The same situation probably obtained in Case 1 in

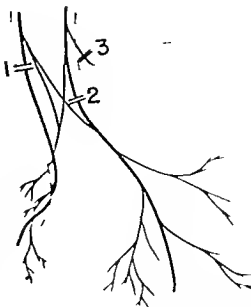


Fig. 4. Diagrammatic representation of the esophageal and gastric vagi following attempted complete vagotomy for peptic ulcer as revealed by postmortem dissection (Patient L.U.—M.S.H. No. 448647). Branches cut (about 60-80 per cent of the total) 1 Main posterior division of the left vagus 2 Main anterior division of the left vagus 3 branch of the left vagus to the diaphragm.

which physiological evidence of some vagal integrity was afforded by the response to insulin hypoglycemia.

CASE 3 L. R. (M.S.H. No. 464135 O.P.D. No. 39-3613) First admission, February 10, 1939. This patient was a 43 year old male, with a proved bleeding duodenal ulcer which had been treated medically for several years. After several weeks of conservative therapy a subtotal gastrectomy was performed. The preoperative Rehfuess test showed maximum free and total acidities of 95 and 110 units respectively at 2 1/2 hours.

Second admission, August 14, 1940. There had been no complaints referable to the stomach for 14 months, at which time persistent epigastric pain recurred. Gastrointestinal series revealed a jejunal ulcer. Under medical therapy he improved and was discharged.

Third admission September 11, 1940. Patient was readmitted for severe pain which had recurred several days after leaving the hospital. At this time the stools were positive for occult blood. He again improved on a medical regimen and was discharged.

Fourth admission, October 31, 1940. Readmitted again for recurrence of pain. Surgery was felt to be indicated and for recurrence the patient was explored on October 31, 1940. A small remnant of stomach with a gastrojejunal ulcer was evident. The smallness of the gastric segment precluded further resection. Therefore an anterior vagotomy together with a Sierlin procedure was performed, to insure complete division of the anterior vagus supply. A specimen removed showed nerve tissue without pathological change. A complementary Witzel jejunostomy for alimentary change. The postoperative course was complicated by the development of a bronchopneumonia from which the patient eventually recovered. Jejunal alimentation was often accompanied by a sensation of burning near

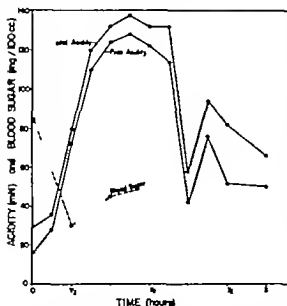


Fig. 5. Acidity and blood sugar curves for insulin test after (partial) anterior vagotomy plus Sierkja circumducing vagotomy on the anterior surface for peptic ulcer (Patient L.R. M.S.I.L. No. 464 35).

the jejunotomy tube. A postoperative insulin test revealed high acid response (Fig. 5) despite the apparently complete anterior vagus section. Such had been done. One year later there was recurrence of epigastric pain (December 30, 1941) for which the patient was treated medically in the out-patient department.

Fifth admission, December 9, 1942. Patient admitted for recurrence of epigastric pain and one episode of gross hematemesis. He was treated conservatively. Alcohol test meal revealed maximum free and total acidities of 45 and 55 respectively.

Anterior vagotomy in this case resulted in no appreciable acid diminution and in only a temporary alleviation of clinical symptomatology.

CASE 4. F.B.L. (M.S.I.L. No. 435356, O.P.D. No. 38-53). First admission, November 4, 1938. This 40 year old male patient was admitted with a year history of burning postprandial epigastric pain, relieved by milk and alkalis, and loss in weight of 50 pounds. Gastrointestinal series had revealed the presence of duodenal ulcer. Physical examination showed chronically ill male with moderate right upper quadrant tenderness. The blood pressure was 115/90, hemoglobin 10 per cent, blood urea 26 milligrams per cent, blood Wassermann, negative. Rehfuess test meal and fasting axitic gastric secretion revealed maximum acid figures of 45/80 and 95/16, respectively. Subtotal gastrectomy plus anterior vagotomy was performed, and the specimen of tissue removed revealed nerve tissue without pathological change. The postoperative course was complicated by the development of duodenal leak with infection of the drainage tracts. Complete recovery ensued, and the patient was discharged 6 weeks after operation.

Second admission, February 3, 1940. Readmitted for upper abdominal pain and vomiting. Physical examination

was negative, except for slight tenderness about the umbilicus. The stool contained no occult blood. The Rehfuess test meal revealed a maximum acidity of only 45 total and 33 free. The patient improved upon Sippy regimen.

Third admission, July 7, 1940. Patient complained of slight diarrhea and abdominal cramps. A gastrointestinal x-ray film follow-up in the out-patient department failed to show the presence of jejunal ulceration. An insulin test showed on preliminary (fasting) acidity; the test acidities were 50 total and 44 free at 3½ hours, and 30 total and 0 free 5½ hours.

The persistence of an acid response to insulin indicates that some of the vagal supply remained. This fact was of course known from the operative procedure performed but it serves to corroborate the validity of the response to insulin as an index of persistent vagal innervation. The hypoaclidity present after operation may not be attributed to the partial vagus section but rather to the subtotal resection of the stomach which is sufficient in itself to account for the diminution in gastric acidity. The response to gruel in the ordinary Rehfuess test meal, which does not depend upon vagus integrity also showed low acid values.

CASE 5. R.S. (M.S.I.L. No. 47439, O.P.D. No. 36-785). First admission, July 9, 1937. This patient was a 4 year old woman who gave an 8 year history of abdominal pain, nausea, vomiting, melena, and hematemesis. The general physical examination was negative. The stools were negative for blood. A gastrointestinal series was negative except for the possibility of diverticulum of the second portion of the duodenum. The Rehfuess test meal showed maximum acidity of 95 total and 80 free. She was discharged with diagnosis of abdominal pain, etiology not determined.

Second admission, October 1937. Readmitted for persistent abdominal pain, a condition which internamitral bleeding had occurred and fibroid uterus was noted. Gastrointestinal series was again negative and she was discharged with diagnosis of fibromyoma uteri and anxiety neurosis.

Third admission, November 30, 1937. The patient reported the recurrence of epigastric pain and burning. Gastrointestinal series now revealed slight deformity of the lesser curvature of the stomach although insufficient for the diagnosis of ulcer. The motility was normal. She improved on medical therapy and was discharged.

Fourth admission, April 7, 1939. She was again admitted for epigastric pain, nausea, hematemesis, and melena (history only). The physical examination was essentially negative. The hemoglobin was 70 per cent. The orange-chewing vagus test meal² showed maximum total acidity of 86, and free acidity of 70. Exploration was decided upon in view of the persistent symptoms, the history of hematemesis, and the equivocal gastrointestinal x-ray films. At operation, the stomach, duodenum, and gall bladder were all negative. The gastric acidity had been moderately high, and it was therefore thought that vagus section might solve the therapeutic problem. This was carried out by exposing the esophagus below the diaphragmatic hiatus and dividing strands of vagus nerve on its anterior and posterior aspects. T. specimens of excised tissue examined microscopically proved to be nerve tissue.

²This test is performed by first aspirating the fasting gastric contents. The patient is then permitted to chew half an orange without swallowing any of it, after which gastric specimens are taken every 15 minutes for hours.

Postoperatively the patient developed a bronchopneumonia from which she recovered without sequelae. She also suffered from marked delay in gastric emptying. The stomach became dilated, and several thousand cubic centimeters of stomach contents had to be aspirated daily. A postoperative orange-chewing "vagus test" revealed maximum acidities of 83 total and 40 free. The gastric retention subsided, and the patient was discharged to the out patient department.

In the out patient department a gastrointestinal series on June 31, 1939 showed no ulcer. There was a 25 per cent 6 hour gastric residue. On July 21, 1939, a methylene blue and alcohol test meal showed maximum figures of 100 total acid and 55 free. Methylene blue was present in all specimens for 3 hours. Gastrointestinal series on September 20, 1939, was unchanged.

Fifth admission, October 18, 1939. The patient was readmitted with complaints of foul breath and regurgitation of food, especially on bending over. Physical examination was still essentially negative. A Gruel test meal showed fasting acidities of 12/54 and maximum acidities of 51/58. The orange-chewing test showed no fasting acid and acidity values of 35/70 in the third hour. An insulin test was done, but no hypoglycemia was obtained (the blood sugars were fasting 90, 40 minutes 90, 3 hours 65) and therefore no free acid response was obtained, in accordance with expectation. On medical therapy the patient improved and was discharged.

Sixth admission, February 16, 1940. The complaints were epigastric fullness and vomiting, and physical examination revealed no change. A gastrointestinal series again showed a 25 per cent 6 hour residue, but no evidence of ulcer. Slight improvement occurred in the hospital, and the patient was again discharged.

In follow up, a gastrointestinal series revealed normal motility of the small bowel and stomach on March 10, 1941. On September 9, 1941 she complained of persistent epigastric fullness and occasional vomiting. An insulin test on March 18, 1942 showed the fasting blood sugar was 70 milligrams per cent, and 35 minutes after insulin injection it was 30 milligrams per cent. The fasting acidities were 25/55. At 1/2 hour they were 35/50 at 1/4 hour 40/60 at 3/4 hour 50/60 at 1 hour 80/115, at 1 1/4 hours 80/115 at 1 3/4 hours 75/110, and at 2 hours 60/90.

The problem in this case was obviously unsolved by the surgical therapy utilized namely partial vagotomy. From the point of view of the physiological effects of partial vagotomy how ever the case illustrates rather strikingly that although sufficient of the vagal fibers to the stomach had been severed to produce prolonged delay in the gastric emptying time, a persistent and vigorous acid response to the insulin and other tests remained.

CASE 6. J. A. (M.S.H. No. 488057, O.P.D. No. 34-19054). First admission, May 9, 1942. This patient was a 49 year old male with a 10 year history of postprandial epigastric pain and vomiting. He had lost 60 pounds in weight during this period. Physical examination was negative, except for a thin habitus and an emphysematous chest. Blood pressure was 124/90. The urine and blood Wassermann were both negative. The hemoglobin was 85 per cent. The blood urea was 18 milligrams per cent, blood chlorides 555 milligrams per cent, carbon dioxide combining power 57

volumes per cent, total protein 6.9 milligrams per cent. The electrocardiogram was negative. A gastrointestinal series revealed a deformed duodenal bulb. Test meals before operation showed the following:

Test meal	Maximum acidity (free/total)	
	35/50 (Fasting—55/70)	
Alcohol	40/60	
Gruel	55/60	
Night	112/118 (Blood sugar minimum	
Insulin	35 mg per cent)	

Posterior gastroenterostomy with anterior vagotomy was performed by Dr. Percy Klingenstein. The upper end of the stomach was exposed at the lower end of the esophagus. All areolar tissue was divided down to the muscularis. A typical posterior gastroenterostomy was then performed. Moderate gastric retention was present post-operatively to the 14th day. Postoperative test meals showed the following:

Test meal	Maximum acidity (free/total)	
	10/30	
Alcohol	60/101 (Blood sugar minimum	
Insulin	30 mg per cent)	

Follow-up notes, July 8, 1943. The patient gained 16 pounds and complained only of slight regurgitation after breakfast. December 23, 1943. There has been an additional gain of 12 1/2 pounds. No complaints.

This case also demonstrates a definite acid response to insulin after partial vagotomy with values only slightly lower than preoperative figures. How much the vagotomy contributed to the symptomatic improvement it is impossible to state since we know that gastroenterostomy alone is quite able to effect such improvement.

THE VALUE OF PARTIAL VAGOTOMY

A critical review of the literature leaves one unconvinced as to the value of partial vagotomy in the therapy of peptic ulcer. Even Latarjet whose procedure is most likely to sever all the vagus supply to the stomach advocated an additional surgical procedure, gastroenterostomy. In the series reported by Winkelstein and Berg, 26 cases out of 34 developed achlorhydria. Of these however only 16 were immediate, the other 10 developed achlorhydria later. It is difficult to see how section of a nerve can produce a delayed loss of function in the organ innervated. One would expect an immediate result or none at all. On anatomical grounds, moreover the entire posterior mucosal surface of the residual stomach re-tained its innervation and therefore would continue to secrete acid if severance of the nerve supply were the only therapeutic factor involved. The high percentage of cases in which achlorhydria was achieved and the beneficial therapeutic effects reported by these authors, must therefore

be attributed to the partial gastrectomy rather than to the partial vagus section.

The work on pouch dogs previously reported by us demonstrated that secretory impulses arising in the central nervous system continue to be transmitted to the stomach pouch even after loss of most of the vagal innervation. One should also recall that much of the fundamental work done by Pavlov and his school on the conditioned reflex involved the use of a pouch which has been demonstrated to have been deprived of the bulk of its vagal supply. It is difficult, in light of this, to visualize how one can hope to eliminate the so called psychic element in the therapy of peptic ulcer by partial vagus section. Moreover the elimination of the psychic and nervous phases of secretion *in toto* would not necessarily solve the problem, since the other (chemical) phases of gastric secretion may very well be factors of such magnitude as to overshadow completely the psychic phase in importance. This was demonstrated in the pouch dogs of our experimental series, in which Heidenhain or completely denervated pouches, as often as not, gave postprandial responses indistinguishable from those of pouches with varying degrees of innervation. Therefore too much cannot be expected therapeutically even from complete vagus section.

The conclusions to be drawn from the 6 cases reported here are limited, as they are in any clinical study in a small series of isolated cases. Most of the cases presented exceedingly complex problems, and vagotomy was employed only as a last resort. The series was shortened by reluctance to continue a procedure which seemed to offer little therapeutically and which introduced a definite increase in operative risk. From a therapeutic point of view it would seem that complete vagotomy would have more to offer in reducing the acid or producing achlorhydria than partial vagotomy. Whether this would be offset by the disadvantages of motility alterations observed in several of our cases is open to speculation. However complete vagotomy is extremely difficult to achieve technically without appreciable increase in the operative danger. Through a transpleural approach the exposure is good, and complete division of the vagus supply would therefore seem easier through this route. Actually even with the best of unilateral exposure it is far from a simple matter to expose all sides of the esophagus, and because of the rich branching and anastomosing of nerve fibers about the lower esophagus, which some anatomists have described as an esophageal plexus, many of the smaller branches will escape the most determined and careful operator. This

approach also severs the vagus trunks proximal to the large branch to the celiac plexus which supplies the remaining abdominal viscera and it therefore may interfere with the function of these organs. The risk of the transpleural supradiaphragmatic approach is a real one and the procedure should accordingly not be considered lightly. Subdiaphragmatically complete vagotomy is more difficult to achieve since the problem of rotating the esophagus or upper stomach to afford access to all sides is clearly neither simple nor atraumatic. Actually none of the cases in our series had a complete vagotomy although this was attempted in two instances. Anatomical dissection in one case and the insulin test in all six proved the persistence of vagal fibers.

The benefits derived from partial vagotomy in our series are questionable. The first case in which supradiaphragmatic vagotomy was performed was certainly unimproved and subsequently developed a recurrent jejunal ulcer. The second died. The third a gastrojejunal ulcer had a recurrence of symptoms 9 months after anterior vagotomy and the Sclerlin procedure were performed. The fourth, 3½ months after subtotal gastrectomy and anterior vagotomy developed recurrence of pain and vomiting although he has been well since. However one cannot say that the partial gastrectomy alone would not have done equally well. The fifth case (in which partial vagotomy alone was performed) certainly was not improved clinically and instead developed difficulties in motility after the procedure. The sixth case is too recent to draw conclusions as to the therapeutic effect. All cases showed a persistence of acid response to insulin proving not only that vagotomy had been partial, but that little reduction in the nervous phase of gastric secretion can be expected from such partial vagotomy. It is true that most of the cases presented exceedingly difficult problems, but in the present state of our knowledge there is little reason to employ the procedure in the simpler variety of cases, and it certainly does not warrant incurring the added risk involved in the trans thoracic or even the subdiaphragmatic vagotomy.

SUMMARY AND CONCLUSIONS

1. A brief review of the literature on gastric vagotomy and its experimental and clinical effects is presented.

2. Experimentally it is shown that little diminution in the nervous phase of gastric secretion is to be expected from partial vagotomy while the other (chemical) gastric secretory phases are entirely unaffected. The insulin test is an unfailing

means of determining the persistence of part of the gastric vagus supply

3 Six clinical cases are presented in which vagotomy was performed either alone or in conjunction with some other operative procedure. The therapeutic problem in most cases was difficult and had not responded to ordinary measures. In 3 cases the lesion was a gastrojejunal ulcer following partial gastrectomy in 2 it was a duodenal ulcer and in 1 there existed severe functional complaints without any demonstrable organic lesion. In only 2 cases was complete vagotomy attempted but in neither of these was it achieved. The validity of the insulin test as an index of persistent vagal innervation was upheld by the studies in these cases.

4 In none of the cases was clear cut evidence of beneficial therapeutic effect obtained. Instead a definite increase in operative risk and morbidity was encountered. The inefficacy of the procedure clinically bears out what had already been observed in the laboratory namely that partial vagotomy does not influence the nervous phase of gastric secretion significantly and that even if it did, the other secretory phases may overshadow the nervous phase to such an extent as to render it unimportant.

5 Accordingly gastric vagotomy alone cannot be recommended as a therapeutic procedure complete vagotomy because of its risk difficulty of accomplishment, possible effects on motility, and only questionable influence on secretion and

partial vagotomy because of the absence of any beneficial effects whatever

Following completion of this paper 2 cases of supra diaphragmatic bilateral vagotomy were reported by Dragstedt and Owens². Both of these patients appeared to have been benefited by the operation, but the period of observation was of only a few months duration. There was a considerable reduction in night secretion but not total elimination. Neither the insulin test nor any other test for vagal continuity was performed

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THE SURGICAL TREATMENT OF CORROSIVE GASTRITIS

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CORROSIVE gastritis results from the ingestion of corrosive substances, the most common of which are those most frequently used in homes and industry, namely lye (alkali) and mineral acids.

The surgeon usually encounters patients when they begin to suffer from the sequelae of corrosive gastritis. These sequelae are manifested by symptoms of pyloric obstruction. Since these sequelae may not be evident until many months following the intake of a corrosive substance the patients often do not associate their present symptoms with the past mishap. Therefore the patient should be asked directly as to a possible intake of a corrosive substance since otherwise he might not regard such an occurrence as significant.

The nature of the injury sustained by the esophageal and gastric mucosa from ingestion of a corrosive poison determines the future course and the type and time of appearance of symptoms. As a rule, the more severe the initial symptoms, the stormier the immediate course, the more marked the sequelae, and the sooner the symptoms of obstruction will appear. Weak corrosives may give rise to only mild secondary symptoms.

The reaction of the corrosive used, whether acid or alkaline, has a particularly important bearing on the site of the permanent damage. Symptoms of dysphagia will appear more often and much sooner after the ingestion of an alkaline corrosive (lye) than after an acid. Indeed, in most instances of corrosive gastritis due to an acid in our series, the patients presented themselves not because of dysphagia but because of symptoms of gastric obstruction. On the other hand, following lye ingestion dysphagia was the earlier and more prominent symptom.

The sequelae of corrosive poisoning are characteristically determined by the type, amount and concentration of the substance swallowed, and by the state of the stomach when the ingestion of the corrosive occurred, i.e., whether full or empty. The ingestion of lye results in an involvement of both the esophagus and stomach. The esophagus,

however, is more severely involved since the lye is somewhat more diluted when it reaches the stomach. Acids, on the other hand, seem only to scorch the esophageal mucosa during their rapid course through the esophagus, but corrode the gastric mucosa with which they are in longer contact. Larger amounts and higher concentrations will obviously cause greater damage. In case of a full stomach the gastric contents dilute the corrosive agent so that the damage may be minimal and involve only the pyloric region and the lesser curvature. When the stomach is empty and contracted during the swallowing of a corrosive liquid the latter comes in contact with the entire gastric mucosa, particularly that of the antrum and pars media, so that marked corrosion occurs in these areas. If perforation with resulting peritonitis does not occur in the corroded areas, ulceration with secondary cicatrization of the walls ensues resulting in marked narrowing and ultimately in stenosis of these portions. Thus, the end result of a healed corrosive gastritis is at best a pyloric stenosis with involvement of the distal part of the antrum and at worst a gastric stenosis with involvement of the distal half or more of the stomach. Regardless of the extent of involvement, surgical intervention for creation of a new opening becomes necessary in most instances.

Once the diagnosis of a corrosive gastritis has been made, the question arises as to what surgical procedure is indicated. To answer the latter at times is difficult. As a rule, if the patient presents himself to the clinician with signs of pyloric obstruction several months after drinking the corrosive liquid, the pathologic sequelae of that mishap may be mended by a simple gastroenterostomy. If however the corrosive agent was ingested only a short time before, the condition is acute and the surgical procedure will depend on the finding at laparotomy. Thus, if at operation the surgeon finds the stomach edematous and friable with much perigastric inflammation and adhesions, it is better to terminate the operation as a jejunostomy and postpone the operation on the stomach for a later date. Such a step has two advantages. First, it permits the patient to keep in good nutritional status by means of jejunostomy tube feedings. Second, it avoids surgical handling of the stomach during a time when any surgery may be hazardous

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because the gastric wall is edematous and inflamed and thus may not permit good suturing with resulting leakage leading to fatal peritonitis. The latter fact has been stressed particularly by various German surgeons (4, 5). In some instances, a prior jejunostomy will permit the stomach to rest and thus aid in the healing process and in the better demarcation between normal and affected parts of the gastric wall. Moreover in some instances in which the pouch formed by the uninvolved part of the stomach is small and thus presages difficulty during an attempt at anastomosis, a previous jejunostomy will keep the patient nourished while the patient is fed orally until he vomits. Because of the complete gastric obstruction the oral feeding can be considered only as a sham feeding which actually serves only to distend the gastric pouch (Case 2) so that it becomes better suited for gastroenterostomy. If however at laparotomy the stomach except for the pyloric obstruction, is found only slightly affected in spite of the recent history then an immediate gastroenterostomy may be performed. In patients with corrosive gastritis, gastroenterostomy is not a generally prohibited procedure as in those with duodenal ulcer because due to the destruction and scarring of the gastric mucosa by the corrosive agent secretion of acid is usually eliminated, a fact which diminishes the possible incidence of marginal ulceration.

In spite of some opinions to the contrary (2), we believe that jejunostomy should be performed in these cases whenever the surgeon at laparotomy has even the slightest doubt about the condition of the gastric walls. Frailty, inflammation and edema of the gastric walls spells failure for any attempt at gastric surgery. Haste to perform the gastroenterostomy is dangerous. A preliminary jejunostomy may mean the difference between success and failure in that it permits replenishing the patient's nutritional losses, and healing of the gastric walls and better demarcation of the affected parts. We believe that if vomiting starts soon after the ingestion of the corrosive agent and is not relieved by a medical regimen preliminary jejunostomy is indicated even though one might consider such a procedure superfluous with the present day facilities for intravenous alimentation. That this does not hold true was recently demonstrated by the case of a 3½ year old child who drank a corrosive substance by mistake and who came under our observation about 4 weeks after the onset of vomiting. During this time she was given only intravenous fluids with occasional plasma and blood transfusions. She lost 10 pounds and was quite emaciated and protein de-



Fig. 1. Large stomach due to pyloric obstruction following hydrochloric acid ingestion.

ficient when operated upon. At operation, only the fundic portion of her stomach was found uninvolved. An anterior gastroenterostomy was performed. The child made an uneventful recovery but is regaining her weight only slowly even though she eats fairly well, a fact which may be blamed on the prolonged starvation before operation.

CASE REPORTS

The following case reports are representative of patients who came to the hospital because of sequelae of corrosive gastritis.

E. W. a 50-year old male, was admitted to the hospital with a history that for the past 3 days he had been drinking heavily and about 3 hours ago he took a glass of muriatic acid by mistake. A doctor was immediately called who gave him a glassful of sodium bicarbonate solution. Since then he had frequent watery evacuations of brownish color mixed with blood. Physical examination revealed a middle aged white man of acutely ill appearance and in great pain; pulse, 140; temperature, 98 degrees; blood pressure, 130/0. There was no excoriation of the lips, the palate and uvula were edematous and swollen, the pharynx looked red and there was some tenderness over the epigastrium. There were no other findings.

On entrance to the hospital the hemoglobin was 85 per cent, red blood cells 4,430,000, white blood cells 14,200 with 85 per cent polymorphonuclear cells. The urine was negative. After 4 days the temperature which had reached



Fig. 2. Roentreeogram showing marked gastric deformity following the drinking of hydrochloric acid on fasting stomach.

degrees shortly after entrance became normal. The patient, as given fluids intravenously and eat slowly but all except for some difficulty swallowing, took gradually cleared up. He left the hospital 3 days later being able to take food without complaints.

He returned to the hospital 3 months later complaining of vomiting, epigastric pain, and belching. These symptoms supposedly had been present for the past 3 months. While he was under observation at the gastrointestinal clinic, X-ray films of the stomach revealed high grade pyloric obstruction (Fig. 3). The patient was therefore admitted to surgical and examination there was essentially negative except for signs of marked right lobe. Pyloric obstruction on the basis of corrus, poisoning as diagnosed and the patient was operated upon. At operation the wall of the lower half of the stomach was found to be very thick, the mucosa appeared scarred and ulcerated, and the pylorus was stenosed. A posterior jejunostomy was performed. Patient made uneventful recovery and left the hospital 2 weeks later.

L.S. female, 35 years of age, was admitted to the hospital with the history of being drunk, 3 months prior, small amount of hydrochloric acid with suicidal intent. She was rushed to physician's office where her stomach was lavaged. Following that she experienced mild subnormal and epigastric distress which at times became associated with vomiting and later with vomiting of every thing she ingested. Sedatives and antispasmodics gave her no relief. Physical examination of the patient was essentially negative. An X-ray examination of the stomach revealed that there was marked deformity of the lower two-thirds of the stomach, with only small portion of the fundus being intact (Fig. 4).



Fig. 3. Same gastric pouch as in Figure 3 months after jejunostomy feeding and oral sham feeding. Note enlargement of gastric pouch and jejunostomy tube in situ.

After suitable preparation, exploratory laparotomy was done at which time marked peritonitis was noted. The stomach wall was thin and the union of the posterior almost too small to permit gastroenterostomy. Therefore, jejunostomy was done and the patient fed through tube for 3 months. At the same time she was fed orally in order to distend the undistended part of the stomach (Fig. 5). All the oral feeding was omitted. At the end of 3 months, second laparotomy was done and at that time an anterior gastroenterostomy was performed. The patient made an uneventful recovery except for some slight esophageal stricture which responded to dilatation. She has been doing well since (8 years).

M.S., male, 5 years of age, was admitted to the hospital with complaint of eight (8) days for vomiting and vomiting for the past 4 days during which time he was not able to keep down even liquids. The physical examination revealed only an emaciated little male with no other findings. The X-ray examination of the stomach was reported as infiltrating growth involving the lower three-fourths of the stomach, dilatation of the cardia, pylorus stiff and unchanging. No barium passed through the end of 6 hours. Diagnosis: Far advanced malignancy of the stomach with complete obstruction (Fig. 6). The patient was then transferred to surgery as a case of carcinoma of the stomach.

Additional history in the surgical ward revealed that several weeks prior the patient drank, first entirely some cleaning polish containing sulfuric acid, which he mistook for wine. The diagnosis was changed, therefore, to corrosive gastritis and the patient was prepared for laparotomy. At operation the lower third of the stomach appeared constricted with marked dilatation of the upper two-thirds. An anterior gastroenterostomy was performed. Patient made



Fig. 4. Large fundic portion of stomach with lower half represented only by a small tube-like projection due to scarring following the intake of "shoe polish cleaning fluid."



Fig. 5. Complete obstruction of lower portion of stomach after child drank a fluid containing zinc chloride

an uneventful recovery and is getting along well, being able to eat the average bland diet. X-ray examination of the stomach 3 months after the operation revealed a large well functioning stomach.

M. D. 334 year old child, while playing in the yard, drank some liquid from a discarded bottle. This liquid was found later to contain zinc chloride. She was rushed to a hospital in the vicinity where gastric lavage was performed, after which she was sent home. Several days later the patient began to vomit everything she ingested including liquids. She was admitted to a hospital where she was given intravenous fluids for about 2 weeks before she was sent to Cook County Hospital.

An x-ray examination of the stomach taken at the outside hospital and also at the County Hospital revealed a complete obstruction of the distal part of the stomach with the remaining fundic pouch only about the size of half a dollar (Fig. 5). The child was prepared for operation with plasma, whole blood, and fluids. At exploratory laparotomy the distal two-thirds of the stomach were found completely stenosed. An anterior gastroenterostomy was performed on the remaining small pouch with great difficulty. The child made an uneventful recovery and has been gaining weight slowly. Follow up x ray examination showed that the small pouch was enlarging and that the toms was functioning well.

These 4 representative histories of patients with corrosive gastritis seen at the Cook County Hospital give first a clear picture of some of the underlying causes. Second they demonstrate the different symptoms and the variable onset of the

sequelae of corrosive gastritis. In most instances this condition is found in individuals of over middle age and therefore the condition is most often diagnosed as carcinoma of the stomach.

In spite of the fact that surgery is indicated in both conditions so that one might argue that the exact diagnosis is unimportant we believe that it is rather of great importance to make an accurate diagnosis before laparotomy is done inasmuch as both the doctor and the patient's family are in a different frame of mind when an operation is performed from a curative than from a palliative point of view. Since corrosive gastritis has a very good prognosis if treated properly, it is obvious that the latter diagnosis carries with it much more assurance to the patient and a much better prognosis than the diagnosis of carcinoma.

Corrosive gastritis is diagnosed as gastric carcinoma not only because of suggestive appearance of the x ray films but also because of symptoms of continuous vomiting, marked weight loss, and achlorhydria. However there is no, or only rarely blood in the stool of patients with sequelae of corrosive gastritis. It behooves the clinician, therefore, to evaluate carefully the obtained history and physical findings in patients who present

"malignant findings" but who don't seem to quite fit into the carcinoma group (1).

Corrosive gastritis is one of the many gastroenterological conditions in which anamnesis is so important because except for the history of a possible ingestion of some such substance, there is rarely any other way by which it can be diagnosed before operation. In many instances, moreover, the diagnosis may not be made by the surgeon even at operation if he is not aware of such a condition. The operating surgeon may see an unusual picture having more of an inflammatory than malignant character but the true nature of the pathology may not be considered unless he is familiar with such a condition or keeps it in mind (3). Not only is it important to differentiate between corrosive gastritis and carcinoma from the point of view of prognosis but also from the point of view of treatment inasmuch as corrosive gastritis requires different preparation and a different type of operation.

Further, in patients suffering from the sequelae of corrosive gastritis there is no danger if surgery is delayed while in the meantime the patient is built up. Then, too, in many of these cases of corrosive gastritis two-stage operations may be necessary, i.e. primary jejunostomy and secondary gastroenterostomy at a later date while in carcinoma this is rarely advisable. The patient with corrosive gastritis is not an emergency case and all possible measures should be taken to build him up to an optimum before surgery is undertaken. In contrast to patients with carcinoma of the stomach patients with corrosive gastritis should be watched for some time before surgery is attempted so as to give the corroded area a chance to delineate itself so that at operation the surgeon can tell with certainty the normal from the affected parts.

SUMMARY AND CONCLUSION

Corrosive gastritis is a pathological condition of the stomach which follows the ingestion of some corrosive substance and which usually requires surgical intervention for its relief. The condition even though comparatively rare is not as infrequent a previously thought and occurs quite commonly among people of the lower social strata as seen in charity hospitals. The sequelae of ingestion of a corrosive substance may occur anywhere from several days to several months later. It is therefore quite common that the patient when seeking relief from his gastric symptoms fails to recall the time of the mishap that is, when he ingested the substance.

Corrosive gastritis is therefore another condition in which is stressed the value of securing a good history in patients with gastrointestinal complaints. All patients with corrosive gastritis whom we have seen required surgical intervention for relief of the gastric obstruction. Gastroenterostomy rather than resection may be done inasmuch as the dangers of secondary gastrojejunostomy ulceration are minimal since in these stomachs there is no free acidity present. Patients with corrosive gastritis have to be prepared carefully and for a long time if necessary by jejunostomy feedings, for the final operation on the stomach. In some cases with very small fundic pouches sham feedings have to be given in order to distend this portion sufficiently to permit the gastroenterostomy.

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HOOK TRACTION UNDER ZYGOMATIC ARCH IN CERVICAL SPINE INJURIES

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SKELETAL skull traction for the treatment of cervical vertebral injuries was first reported by Crutchfield in 1933 (3). Since then McKenzie, Hoen, Cone and Turner, Barton, Selmo, Neubeiser and others have described methods and apparatus for obtaining skeletal traction on the skull in the treatment of fractures, dislocations, and fracture dislocations of the cervical spine. The purpose of this paper is not to discuss the relative merits of the different methods advocated and in use today but to describe a simple apparatus for skeletal traction.

Most methods and apparatus have special advantages and all those described have been effective in maintaining traction on the cervical spine. However all methods except those described by Neubeiser and Selmo require either burr holes in the calvarium through which wires are passed down to the dura or tongs inserted down to the inner table of the skull. Both Neubeiser and Selmo have described methods by which traction is applied to the zygomatic arch on both sides of the skull. Neubeiser reported 1 case in which he used stainless steel fish hooks under the zygomata. Selmo described the application of blunt hooks under each zygomatic arch with a special type of triangular bar used to connect the hooks.

The method described here concerns the use of fish hooks, inserted under each zygomatic arch to which traction can be applied. Since September 1940 we have obtained skeletal skull traction for lesions of the cervical spine by the use of stainless steel (No. 5) fish hooks from which the barbs have been removed. One such hook is inserted under each zygomatic arch. The hooks can be inserted and the traction applied without moving the patient from his bed. With local or intravenous anesthesia the points of the barbless hooks are inserted under each zygomatic arch about 1 inch anterior to the external auditory meatus. Lead up wires from the hook eyes are carried to the top of the head and connected

either to a wood cross bar 8 inches long and 1 inch square or to a triangular traction rod. A rope is tied to the center of the bar or rod and hung over a pulley at the head of the bed. Weights are tied to the end of the rope and the head of the bed is elevated so that the patient's body weight is utilized for countertraction. Fifteen pounds divided between two hooks is the maximum weight used in any of our cases. Crutchfield (4) however reports that he has found 18 pounds inadequate for the reduction in some cases and has used as much as 25 pounds. This is still well within the maximum weight which No. 5 stainless steel fish hooks will bear without straightening out, since by test it was found that they could withstand a pull of 20 pounds on each hook.

With the fish hooks in place, the patient may turn on his side and be given nursing care without difficulty. Disfiguring scars are not left at the site of the hook insertion. In fact after the hooks have been removed it frequently becomes difficult to identify the site of insertion. After trying various types of skeletal skull traction we believe that fish hook traction is the most satisfactory. Eleven patients have been treated by this method without untoward event except that in 1 case it was necessary to remove the hooks after 3 weeks, because there was a mild inflammatory reaction about one hook. Two case histories in which this method proved to be especially efficient are as follows.

CASE 1. N. N. U. H. No. 723545. A 62 year old white male walked into the Outpatient Department manually supporting his head. He found that this support gave him relief of neck pain from which he had otherwise suffered. The patient had been injured 31 days previously and had been treated by bed rest only and with pillows, while acute flexion of the neck was maintained. On examination it was found that the patient held his head flexed forward about 5 degrees. There was marked tenderness over the spinous process of the 5th cervical vertebra. There was limitation of motion of the head in all directions. Weakness was noted in all extremities but was more marked in the upper extremities, with the right hand very weak. Roentgenological examination showed a compression fracture of the 5th cervical vertebra with anterior angulation of the cervical spine at this level (Fig. 1). A barbless fish hook was inserted under each zygomatic arch, and traction was applied. The angulation was overcome in 10 days with

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Fig. 3, left. Case 3. Roentgenogram showing the angulation of the cervical vertebrae at the fracture six months after injury and before any traction was applied.

Fig. 3, right. Case 3. Roentgenogram showing the correction of the angulation 100 days after application of fish hook skeletal traction.



Fig. 3, left. Case 3. Photograph showing patient with fish hook traction in place. Note the hyperextension of the neck obtained.

Fig. 4. Photograph showing fish hook traction in place on patient who had head halter type of traction which produced ischemic ulcers under the chin.

5 pounds of traction (Fig. 3). After the traction was maintained for 4 weeks, spinal fusion was performed, and the traction was continued after operation to prevent recurrence of the angulation. The hooks were removed 6 weeks after operation and a plaster jacket incorporating the neck and head was applied.

Skeletal traction with hooks under the xygoma was especially suitable in this case because with traction so far forward on the skull (Fig. 3) maximum hyperextension was obtained, and since the patient was not admitted to the hospital until 1 month after his injury it was necessary to use 15 pounds of traction to reduce the deformity. Halter type of traction, with so much weight, is very un-

comfortable and if maintained may result in the development of ischemic ulcers under the chin or occiput (Fig. 4).

CASE C. S., U. H. No. 7, 685. A 40-year-old male, 30 years of age, suffered dislocation of the 1st cervical vertebra and multiple fractures of the mandible. This man obviously could not be treated with head traction of the halter type. Fish hook traction was applied and proved to be most satisfactory. Tentacular lining was done during the period of skeletal traction without disturbing the reduced cervical dislocation.

CONCLUSION

Skeletal skull traction by means of fish hooks inserted under the xygomatic arch is simple, safe,

and easy to apply. The procedure can be performed without moving the patient from his bed. The apparatus is obtainable at any hardware or sporting goods store. They can be easily inserted by physicians not especially trained in surgery. The cost is negligible. It would seem that this form of skeletal traction would be especially useful to the armed forces. Steel hooks similar to the barbless fish hooks previously described could be made easily in any machine shop ashore or aboard ship.

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POSTERIOR MEDIASTINAL GOITER

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PARTIALLY intrathoracic goiters occur relatively often, especially in areas of endemic goiter. Their incidence is placed at about 12 to 20 per cent. (2) Completely intrathoracic goiters are much rarer. Wakely and Mulvany had 3 such cases in 1,300 consecutive thyroidectomies. Hunt reported 3 tall intra-thoracic thyroid masses in 651 consecutive thyroidectomies. In Pemberton's series of 4,000 cases, 25 were intrathoracic, and in Crile's series of 11,800 thyroidectomized patients there were 97 cases of this type.

The rarest of the intrathoracic goiters is the type found in the posterior mediastinum. Only 6 such cases have been previously recorded. The Beranda reported a case of what they described as an endothoracic and retroesophageal based-downed goiter which occurred in a 55 year old woman with syphilitic aortitis. Recovery followed removal of the mass through the usual collar incision under local anesthesia.

A second case as reported by Von Hahner in 1935. His patient, a 30 year old woman 5'6", for 20 years, had had "respiratory troubles" with moderate enlargement of the thyroid. In 1935 the visible portion of goiter as reason of the no improvement in the patient's symptoms. X-ray study of the chest 1 year later showed homogeneous shadow of round outline located in the mediastinum on level with the fourth rib. (The left apex appeared opaque.) A lateral view showed this shadow as close to the posterior thoracic wall, but the trachea appeared neither deviated nor compressed. A tumor was diagnosed and radiotherapy advised. Von Hahner however noted slight movements of the supposed tumor with deglutition and advised operation. The sternum was divided down to the third interspace. A tumor as felt, but from the lower part of the right thyroid lobe, row of nodules led into the posterior mediastinum, ending in an intrathoracic mass the size of child's head. The mass was finally freed and removed after rupturing large cyst. The final diagnosis was colloid goiter. Uneventful recovery ensued, with complete relief of all symptoms.

Rohalm's patient was a 55 year old woman with mild thyrotoxicosis and no thyroid enlargement.

Röntgenography of the chest revealed sharply defined mass-like tumor (size of large fist) in the posterior mediastinum, between the spinal column and the displaced esophagus. There are no local pressure symptoms. The X-ray findings suggested differential diagnostic consideration of lung tumor. Aspiration biopsy (with trocar) provided the correct diagnosis—colloid goiter. This patient was not operated upon.

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Two additional cases were reported by Urban from the Catholic Hospital in Linz (Austria). No details are given save that they occurred in a consecutive series of 8,500 goiter operations and both were successfully removed through collar incisions.

The sixth case was reported by Henschel who, in discussing Reuser's paper, stated he had had 1 case of posterior mediastinal goiter in 6,000 consecutive thyroidectomies. He described this case as an intrathoracic retrovisceral retroesophageal thyroid connected to the cervical thyroid by a thin process. His patient exhibited gastric and cardiac disturbances—probably due to pressure on the vagi. Removal of the intrathoracic mass cleared up all symptoms.

The history of our case the seventh to be recorded, follows:

Mrs. R. G. N., 20, 35, 55 year old, left woman, as admitted to the hospital November 20, 1935, complaining of increasing fatigue, nervousness, palpitation, and slight loss. These symptoms came on rather rapidly some 3 months before admission to the hospital. Despite fairly good appetite she had lost 20 pounds in this period. Closer questioning disclosed that she had not been feeling well for about 8 years, having noted increasing fatigue on slight exertion, profuse perspiration, heat intolerance, and tremor of fingers. From time to time she would have bouts of marked nervousness, excitement, irritability and palpitation, all of which she attributed to the menopause. A few weeks before entering the hospital she had become aware of non-productive cough and some difficulty in swallowing. She had been seen and studied in the course of the 8 years before admission to the hospital by a number of physicians (including the Mayo Clinic) all of whom found on X-ray examination of the chest a large shadow occupying the right upper lung field. She was advised to do nothing about this mass. A number of basal metabolic rate determinations had been made and the patient told they were normal.

The past history was irrelevant. She had had 3 normal pregnancies, and the children were alive and well. The women had ceased 9 years previously. There was no family history of goiter.

The salient physical and laboratory findings were as follows: The pulse rate varied from 112 to 118, the blood pressure from 60/70 to 80/80. There was no thyroid tissue palpable in the neck, but the trachea was displaced slightly to the left. Examination of the lungs disclosed moderate impairment of resonance over the right upper anterior chest. The cardiac rate varied from 100 to 110 with normal rhythm, no enlargement, and short, soft, blowing systolic murmur as heard over the entire precordium. There was marked tremor of the outstretched fingers, and slight pitting edema above the ankles.

Numerous urinalyses showed no abnormalities save an occasional trace of albumin and few bile corpuscles. The red blood count was 4,400,000 per cubic millimeter.



Fig. 1. Roentgenogram of chest (anteroposterior view) showing large globular mass occupying right upper lung field.

white blood cells 5,500, with 68 per cent segmented cells, 28 small lymphocytes, and 4 monocytes. The hemoglobin content was 13.1; there was moderate anisocytosis and hypochromia. Blood chemical studies revealed sugar 90 milligrams per 100 cubic centimeters, nonprotein nitrogen 20 and cholesterol 170 milligrams per 100 cubic centimeters. Five basal metabolic rate determinations varied from +45 to +51.

Röntgen study of the chest disclosed a large globular mass occupying the right upper thoracic cavity; on lateral view this mass was seen to lie in the posterior mediastinum.

The diagnosis at this time was thyrotoxicosis, and the mass was believed to be a large intrathoracic goiter although Dr. Arendt (the roentgenologist) felt that we could not exclude a neuroblastoma, which so frequently is found in the posterior mediastinum.

The patient was accordingly prepared for operation—she was given 15 minims of Lugol's solution 3 times daily placed on a high carbohydrate and high protein diet, adequate vitamins, especially B complex, large quantities of fluids, proper sedation and rest. On this regimen the basal metabolic rate fell to +27, the pulse became slower (90 to 100) and the patient gained 9 pounds.

Operation was carried out on December 20, 91. Intratracheal ethylene anesthesia was used throughout. The neck was opened through the usual collar incision and the strap muscles were separated. Preliminary exploration revealed no thyroid tissue in the neck. On further dissection a small cystic lobe was found on the left, just at the superior thoracic aperture. This was easily and quickly removed. On the right, a thin attenuated pole was found just below the level of the first rib; this was secured and divided between ligatures. On further exploration, a large mass was encountered posteriorly and lying entirely within the thoracic cage. On careful finger dissection hugging the margins of the mass and with gentle traction upward the tumor was gradually freed. A hemostat was then plunged into the mass, and the liquid and jelly-like contents were removed by suction. This procedure permitted narrowing of the transverse diameter of the thoracic goiter following which it was easy to deliver the entire mass. The neck was closed with one gauze drain which was then removed in 45 hours.



Fig. 2. Roentgenogram of chest (lateral view) showing mass lying in posterior mediastinum.



Fig. 3. Photograph of removed thyroid gland showing huge right lobe and smaller left lobe.

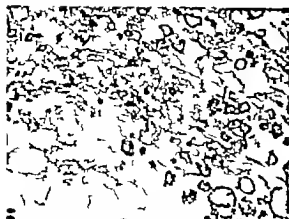


Fig. 4. Low power photomicrograph of section from right lobe showing diffuse edema of stroma separating acini and many infiltrating lymphocytes. The acini vary in size, but most of them are smaller than normal. They are lined with low cuboidal epithelial cells. Roding is marked.

The patient made a smooth and uninterrupted recovery and was discharged in good condition on the eighth post-operative day. The basal metabolic rate was $+3$ three weeks after operation and $+5$ one year after operation. The rate was $+6$ percent. She was quit all this time and gave for mild arthritis (which she had for many years before the operation), she was able to engage in her usual household and social activities. She had gained 4 pounds in the year following removal of the intrathoracic goiter and 10 lb. in the year following evidence of hypothyroidism (parathyroid damage or injury to the recurrent laryngeal nerves).

The pathological report by Dr. T. D. Roberts was as follows:

The right lobe is an encapsulated previously opened soft mass measuring by 9 by 4.5 centimeters and weighing 8 grams. It consists of soft yellow-brown tissue having the appearance of thyroid tissue. The sectioned surface is moist, slightly firm and on scraping yields a fairly large amount of colloid. In some places light yellow-brown areas of somewhat firmer consistency are present. They measure up to 5 millimeters in diameter. In some places hemorrhages are seen. In many areas the capsule shows evidence of separated fibrous connections.

The left lobe is also encapsulated measuring 5 by 3 by 3 centimeters and weighing 6 grams. On sectioned surface it is yellow-red, moist, glistening, and the upper pole presents a calcified nodule surrounded by an area of fibrosis.

Microscopic. The acini of the right lobe vary considerably in size and configuration. Some are very large. They are lined with flat to cuboidal epithelial cells and are filled with pale staining colloid. In some places there is abundant hyaline and edematous tissue scattered throughout these areas and in their vicinity there are many small acini, some of which show active budding and branching. The capsule is infiltrated with lymphocytes in many places. Other areas show evidence of old hemorrhage. Sections from the left lobe show similar picture. There is also a large area of hyaline connective tissue surrounded by very small acini and presenting the picture of microfollicular adenoma.

The pathological diagnosis is right lobe, colloid and nodular goiter (intrathoracic); microfollicular adenoma, left lobe; microfollicular adenoma.



Fig. 5. Roentgenogram of chest (anteroposterior view) one month after operation.

It should be recalled that the intrathoracic thyroid masses are practically always of the adenomatous type. Indeed Lahey (6, 7, 8) and the Criles have repeatedly stated that they had never seen a diffuse goiter (exophthalmic goiter, primary hyperthyroidism) become truly intrathoracic.

The descent of these thyroid masses into the chest is facilitated by a number of factors. These include breathing, swallowing, muscular activity in flexing and rotating the head, nonresistance of the more pliant structures of the thoracic inlet, and gravity. Lahey has described the mechanism of descent of intrathoracic goiters into the mediastinum as follows:

"When an adenoma occurs in thyroid particularly in the left lobe or lower pole of the gland, all the factors are present for propelling that tumor into the superior mediastinum. The adenoma rests above an unobstructed superior thoracic strait bounded in front by the clavicles and sternum and on the sides and back by the vertebrae and first ribs. Any discrete tumor arising in the lower pole, covered as it is by the sternohyoid, sternothyroid, and omohyoid muscles, which limit upward extension by their attachments to the hyoid and thyroid cartilage and which are inserted into the chest wall in front, is subjected to pressure in the downward direction with every act of swallowing.

Clinically the patients with this lesion fall into one of four groups. (1) those with no symptoms,

(2) those exhibiting signs and symptoms of thyrotoxicosis (3) those exhibiting pressure symptoms (4) those with the combination of pressure symptoms and toxicity.

In a relatively large number of patients with good sized intrathoracic goiters there are no symptoms. This is especially true of some of the large masses that expand into the lung fields without producing symptoms of tracheal compression.

The second group requires no comment. In the Cleveland Clinic Series (3) hyperthyroidism was present in 50 per cent of all patients operated upon for intrathoracic goiter. The chief structures involved are the trachea and the great vessels. With tracheal compression the chief clinical manifestations are dyspnea, choking sensations and stridor. Dilatation of the veins of the upper chest and neck are evidence of compression of the great vessels in the thorax. Cough, dysphagia, changes in the quality of the voice, and hoarseness are rare. The latter occurred in 2 per cent of Crile's cases. The esophagus and recurrent laryngeal nerves are rarely involved. One should suspect a malignant lesion if there is any involvement of the recurrent nerves.

Careful roentgen study of the chest with anteroposterior and lateral views will aid in substantiating the diagnosis. It is especially important to observe movement of the mass on deglutition under fluoroscopy.

The treatment of intrathoracic goiter is surgical removal. Lahey (6, 7, 8) and Clute (2) have repeatedly stated that it is unnecessary to remove any portion of the bony thoracic wall to facilitate extraction of the large masses. It is much easier to reduce the size of the intrathoracic goiter. The technique is briefly as follows. Intra tracheal anesthesia is used and the approach is through the usual collar incision. The strap muscles may or may not be divided. The superior pole is secured from above and gentle traction is applied to the upper portion of the mass. With the fingers encompassing the mass gentle, slow dissection is carried out (hugging the capsule) and gradually freeing the goiter. When a good portion of the tumor

has been freed the finger or a hemostat is pushed through the capsule thus permitting the jelly like contents to ooze out and making the mass smaller in all diameters. With a little additional gentle traction the thoracic goiter may then be easily delivered. It is surprising to note how little bleeding occurs especially if one has remained close to the thyroid capsule during the process of finger dissection.

SUMMARY

A case of posterior mediastinal goiter is presented the 7th recorded instance of this lesion. This thyroid mass was removed from the thorax through the usual collar incision without dividing the neck muscles and without removing any portion of the bony thorax. Attention is directed to the salient etiological and pathological features of large intrathoracic thyroid masses, as well as their important clinical manifestations and diagnostic features. In the surgical removal of these large intrathoracic goiters it is unnecessary to remove any portion of the thoracic cage. Their delivery from within the chest may be facilitated by securing the blood supply from above careful finger dissection hugging the capsule, combined with steady gentle traction from above and narrowing the transverse diameter of the mass by removing some of the liquid and jelly like contents.

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A COSMETIC METHOD OF OPERATING UPON VARICOSE VEINS

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IN the past few years there have appeared in medical journals a number of articles pertaining to the treatment of varicose veins. Military surgeons are particularly interested in this treatment because a successful removal of varicose veins substantially improves the physical fitness of the soldier. I would like to call attention to a method which we have employed, since 1927 in many hundreds of cases with very satisfactory results. First of all I want to mention how we developed this method after years of experimenting and then I shall describe the treatment and point out its advantages.

Since 1924 I have seen, and have also had the opportunity to perform personally various types of both operative and conservative methods for treatment of varicose veins. Several methods of extirpation have been tried—from the removal of a single varicosity to the extirpation of the entire saphenous vein, this being done by longitudinal oblique, or curved incision. We have also performed subcutaneous evulsion of the vein by means of Babcock's vein extractor. In a few instances we have tried multiple percutaneous ligation of varicosities. In other cases we limited the procedure merely to the simple ligation of the long saphenous vein in the upper part of the thigh.

Our aim was to obtain the most permanent and at the same time the best cosmetic result. With that aim in mind we hoped that the method of Klapp would prove successful. This method consists of several subcutaneous dissections of the varicosities after high ligation of the long saphenous vein. From only few skin incisions (3 to 5) the vein is cut subcutaneously by means of a strong tenotome (so called saphenotome). Several radiating dissections (transections) of the varicosities are performed from each wound. Therefore, during the year 1925, we abandoned all other methods, operating exclusively by this method. After some experience we realized that the procedure partially failed to fulfill our expectations. After a retrospective survey of all results, it became apparent that our failures were due to the fact that radiating dissection did not accomplish the result desired sometimes even long portions of the venous track were not completely

severed and consequently the blood was not entirely emptied from the veins. Hematomas appeared often in the subcutaneous tissue and thrombosis developed in the vein from the remaining blood. Subsequently the thrombotic vein became recanalized and frequently a recurrence of the varicosities appeared.

Therefore we sought new methods in order to improve the results of operation. At that time medical literature emphasized the injection treatment. In an attempt to form our own opinion of that procedure, we limited ourselves throughout the year 1926 to use of the injection treatment, reserving operation for only very large varicosities. For the injection, we used various sclerosing solutions recommended in literature at that time, chiefly a 66 per cent solution of glucose. However the injection treatment alone did not satisfy us. Even when a compression bandage was applied on the extremity immediately after the injection, hard infiltrations formed along the course of the vein, indicating artificial thrombosis. Complete healing sometimes took weeks or even months. In the process of healing the thrombi became organized due to the entry of the capillaries of the *vasa vasorum*. New capillaries formed an anastomosis which gradually became dilated in the longitudinal direction thus giving rise to a new venous blood circulation. As the valves of the recanalized vein remained incompetent blood stasis in the vein quickly recurred. We then had to deal with the recurrence of the varicosities. Moreover the cosmetic effect was far from satisfactory. Blood clots formed in the veins after the injection of the sclerosing solution, became organized, and formed hard fibrous nodules, which were quite visible even through the stockings. The fibrous nodules also caused difficulty during later operations. They could not be removed by subcutaneous dissection of the vein only but required a special skin incision. Furthermore, the cosmetic result after such a procedure, especially in women, is very often unsatisfactory.

In addition, the danger of embolism is to be considered. Delbet, in his comprehensive monograph on varicose veins, did not encounter a single case of embolism in 700 cases of thrombosed *venae saphenae*, which would seem to exclude the

possibility of embolism arising from vena saphena magna. However I have seen 2 cases of fatal embolism arising from unligated saphenous veins. In the first case death occurred the third day after the injection of a strong sclerosing solution into the vein. The injection was performed in an out patient department of a sanatorium. The second case was observed at our clinic, a patient who had been treated in a conservative manner for thrombophlebitis venae saphenae. Post mortem findings revealed that death resulted from an embolus which was torn away from a blood clot lodged inside the saphenous vein. After this experience I could not agree with Delbet in his opinion that there is no danger of embolism following the injection treatment.

Therefore, during the later months of 1926 we combined the treatment by injection of glucose with the previous ligation of the saphenous vein in the upper part of the thigh. This was done particularly in cases of large varicosities. But even this combined method did not prove entirely satisfactory. Permanent results were achieved only in about 20 per cent of the cases in which the Brodie-Trendelenburg test was positive before the operation. In the remainder of the cases recurrence became apparent shortly after operation, and the histological findings revealed that this was due to recanalization of the thrombi. Thrombosis occurred because some blood always remained in the vessel in spite of the fact that compression bandages were applied immediately after the injection.

For that reason we considered it advantageous to retain the sclerosing solution in the vein only for a short time so as to produce an irritation of the intima and then after cutting the entire length of the varicose vein subcutaneously into the shortest possible segments, to expel all blood mixed with the injected solution from the vein so as to prevent any formation of blood clot. For this purpose we considered the best method to be multiple subcutaneous dissections of the saphenous vein, each performed from a separate puncture and followed by expelling all venous content through the small skin apertures. The walls of the vein after being completely emptied of blood must be pressed together by bandage so that the intima of one side touches and unites with the intima of the opposite side. Only such immediate union precludes recurrence because the walls of the vein are so closely in contact that the presence of any tissue which could later become recanalized is rendered impossible. The cosmetic result is perfect as the varicosities disappear completely without any trace and there is no

formation of fibrous nodules which can so often be seen after the simple injection treatment. The multiple transections of the vein completely destroy its continuity thus making any future recanalization impossible and thereby securing a permanent result. Furthermore, any sclerosing solution which may not have been completely expelled through the apertures in the skin and may have remained in the paravenous tissue, can only contribute to a more complete union and obliterate any pieces of vein resulting from previous multiple dissections. For subcutaneous dissections of the veins we now use instead of a tenotome a delicate scalpel introduced by Graefe for eye operations. Punctures made by this scalpel are very small and heal completely without leaving scars, thus assuring the cosmetic result of the operation. I have used this combined method from the beginning of 1927 up to date in many hundreds of cases however my available records are only from 1927 to 1933 with about 350 cases. My colleagues at the clinic and in other hospitals, who also employed this method were so satisfied with the immediate and permanent results that they have used it exclusively for a number of years.

The operative procedure itself as well as the postoperative treatment requires the fulfillment of some principles which I consider to be of utmost importance. After the general examination of the patient preoperatively we carefully examine both lower extremities for any signs of inflammation. Any purulent process, any inflammation of the veins or lymphatics must be dealt with first and completely healed. Previous thrombosis of the deep veins, even if it occurred many years ago is a contraindication to a radical operation of superficial varicosities. (Varicose ulcers will be dealt with later.) After thorough cleansing and shaving of the extremities up to Poupart's ligament, the patient is required to stand so that the varicosities become more visible. All nodular enlargements as well as the venous course are marked on the surface of the skin with a stick of silver nitrate. A cotton applicator is then dipped into a photographic developer and traced along the same areas thus causing black lines to appear on the skin thereby indelibly marking all the veins and their tributaries. When the patient puts his weight on the marked extremity the varicosities become even more prominent. It is recommended that the surgeon prepare the patient himself as in this way he can ascertain the depth and the location of all the varicosities. This increases the speed and thoroughness of the operative procedure. At

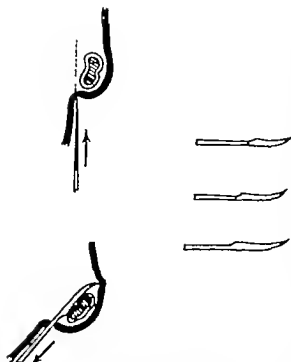


Fig. Diagram showing method of dissection of vein

the same time, we mark the place on the upper part of the thigh where the incision for the saphenous ligation will be made. The course of the vein can most readily be found by means of palpation, when the patient is in a horizontal position, and when his muscles are completely relaxed. This is especially advisable in the cases of women who have a thick layer of subcutaneous fat.

As premedication before the operation, the patient is given an injection of morphine or morphine and scopolamine (hyoscine). The first part of the operation, the ligation of the saphenous vein and the injection of glucose, can be performed under local anesthesia, especially in simultaneous operation on both extremities. The end of the operation is performed under general anesthesia only.

The skin is cleansed with ether and painted with iodine. The sterile sheets and towels are so spread that the operative field is well exposed. The long saphenous vein is ligated through a short incision across the thigh in the direction of the skin ridges. If the course of the vein has been properly marked, an incision about 1 inch in length will usually suffice. The incision is made 2 to 4 inches below the fossa ovalis in order to avoid the inguinal lymphatic glands, which are

frequently infected in cases of varicose veins. In former years we searched for the great saphenous vein at its entrance into the fossa ovalis, but it was very often suppurated, due to local infection. The saphenous vein on both sides is isolated, doubly clamped and transected. Its proximal stump is then ligated with catgut and a strong blind cannula is introduced into the peripheral stump and fixed in the vein by means of a small artery forceps and a silk ligature. After that 20 to 40 cubic centimeters of 66 per cent solution of glucose is injected into the vein on either side. After cutting the silk ligature, we remove the cannula and then ligate the peripheral vein with catgut sutures respecting its remaining free portion as far as possible. The skin is then sutured with fine silk by means of delicate noncutting needles.

Then a general anesthetic is introduced and the subcutaneous dissections of varicosities are commenced. For this purpose, as I have mentioned before, we use Graefe's eye scalpel. The blade of this knife is about $\frac{1}{8}$ to $\frac{1}{4}$ inch long and curved at its tip the shape being similar to a tenotome and the width between 2 and 3 millimeters. After repeated grinding of the blade it becomes even narrower so that the punctures are barely visible. When operating on both extremities we use two scalpels. It is advisable to sharpen the scalpel after each operation. While the scalpel is being sterilized or when stored, the blades are wrapped in cotton for protection.

An assistant elevates the lower extremity of the patient to the level of his own shoulders, thus minimizing bleeding and permitting better access for the surgeon. The scalpel is placed flatly on the skin at a distance of $\frac{1}{5}$ to $\frac{1}{3}$ inch from the vein. The skin is then pierced at right angles to the course of the vein. We pierce the skin and push the scalpel into the subcutaneous tissue underneath the vein until its point is seen about $\frac{1}{5}$ to $\frac{1}{3}$ inch on the other side of the vein. Now we rotate the scalpel so that its sharp edge is directed against the vein and skin. We lift the point of the scalpel lightly so that it is visible under the lifted skin and then in one quick movement we cut the vein drawing the knife backward (Fig. 1). Care must be taken not to cut through the skin itself. The dissections are repeated at intervals of $\frac{1}{5}$ to $\frac{1}{3}$ inch along the entire course of the vein and all its tributaries. The idea is to cut all veins showing varicosities into small segments. Depending upon the extension of the varicose veins, from 50 to 200 of these subcutaneous dissections are usually performed on a single extremity. Care must be taken to avoid cutting

through a tendon superficial artery or the peroneal nerve.

It is best to commence the dissections on the upper part of the calf just below the popliteal groove continuing toward the foot, because on the elevated extremity the blood flows on the skin toward the thigh thus leaving clean the next operative field. For this same reason we cut first the tributaries of the external saphenous vein, leaving until last the internal saphenous vein where the varicosities are usually largest. Furthermore, to prevent an inflow of blood during this procedure, an assistant grasps firmly the elevated extremity just at the ankles.

When the dissections of all varicosities are finished the blood is expelled from the veins through the skin apertures by means of pressure and light massage with sterile towels moistened in saline. During this step which secures complete emptying of the dissected vessels we progress from the ankle to the knee, applying immediately a sterile compression bandage and making its reversures on the inner side of the leg. As a result of the multiple dissections, only small segments of vessels about $\frac{1}{8}$ to $\frac{1}{4}$ inch in length remain of the varicosities. Their walls emptied and collapsed the subcutaneous tissue must be completely pressed together. Care must be taken to prevent hemorrhage or ischemia of the leg especially when the bandage is carried above the knee. Sterile cotton is then wrapped around the extremity over the first bandage, or immobilization by splint is used.

After the patient has been put to bed the legs are slightly elevated to facilitate better blood flow of the deep veins. As soon as the patient has awakened from the effects of the general anesthetic, we test the mobility of the toes and feet, then the sensitivity and discoloration of the skin to be sure that there is no compression of some nerve or artery. As a rule, during the first, second and third day after the operation, the toes become slightly swollen but the swelling soon disappears. The compression bandage and the stitches are removed about the seventh post-operative day. The layer of the dressing which is in immediate contact with the skin must be removed with great care in order to avoid tearing off the crusts which have formed over the skin apertures. An ordinary sterile dressing is applied and the patient is kept in bed 7 to 10 days after the operation. When the extremities have been cleansed with alcohol the patient is allowed to walk. He is instructed to wear an elastic bandage for another 2 to 4 weeks this is to be removed at night and worn again in the morning.

COMPLICATIONS

In several instances, we have observed an infection of the wound when the incision had been made at the level of the fossa ovalis. For this reason we now perform the ligation of the great saphenous vein a little lower in order to avoid the lymphatic glands. In 1 case, erysipelas developed from a skin infection which had not completely healed at the time of the operation. Thrombosis of the deep veins occurred in 2 cases, both within 2 or 3 weeks after operation. In one instance it occurred after the classical operation of Klapp.

The most common appearance after the operation is a swelling about the ankles which developed in about 20 per cent of the patients as soon as they began to walk. In some patients this swelling occurred only occasionally for instance, in athletes after extensive exercise. The swelling is greatest in the evening and disappears after a night's rest. This phenomenon passes in about 4 to 6 weeks without any intervention. We consider it to be the consequence of too radical a destruction of the superficial venous system. Sufficient time must elapse before the collateral circulation through the deep veins becomes established. This explanation is confirmed by the fact that no swelling occurs after an operation of very large varicose veins where, due to incompetence of the venous valves, a collateral circulation has been established prior to the operation.

RESULTS

The legs after the operation are smooth without any visible fibrous nodules in the subcutaneous tissue. The scar after ligation becomes white in a few months and the punctures are barely noticeable and if at all only as tiny whitish dots. Recurrences are very rare. In about 10 per cent of the cases we have observed after 5 or 10 years, the recurrence of single varicose knots in the course of the tributaries that had not been operated on and sometimes also at the point of an anastomotic communication with the deep venous system. These recurrences can be easily removed under local anesthesia by means of subcutaneous dissection of the nodules with a Graefe scalpel followed by compression bandage for 7 days. Such a procedure can be performed in the out-patient department.

REMARKS

When the femoral portion of the great saphenous vein is enlarged and tortuous, we combine the described operation with subcutaneous removal of this vein by means of Babcock's vein extractor. Counter incision is performed at the

level of the knee. By means of this incision glucose is then injected into the distal veins which are then transected subcutaneously with a Graefe scalpel.

VARICOSE ULCERS

Very satisfactory results have been obtained by our method, even when varicose ulcers have been present. Before the operation, the base of the ulcer is thoroughly cleansed and compresses of Rivanol or Chlorsamyl's solution are applied for 2 to 3 days in order to sterilize the ulcer and the surrounding tissues.

During the operation the strictest asepsis must be observed. The ulcer is covered with a special towel and, while the saphenous vein is being ligated very special care is taken to avoid the regional lymph glands which are always enlarged and infected in the presence of varicose ulcers. Therefore, the incision is made 2 to 4 inches below the fossa ovalis. When, after the injection of glucose, the peripheral veins are dissected and the blood is expelled any contact with the ulcer must be avoided to prevent any contamination. This part of the operation being completed we then

take a fresh strong scalpel and make several radiating incisions over the edge and base of the ulcer piercing the skin to the superficial fascia. Silver ointment is immediately applied to the ulcer. Nowadays, of course, sulfa drugs may be administered and a compression bandage put on the extremity. (During the course of the present war I have had no opportunity to operate upon varicose ulcers but feel sure that sulfa drugs will be of great use.)

The result is very good. The ulcer heals far more quickly than when treated with any conservative method. As soon as the varicosities which cause the venostasis are removed, the nutrition of the skin and subcutaneous tissue is immediately improved. In the postoperative treatment, a dry dressing is applied and packs are avoided. Heliotherapy and application of nonirritating powder are recommended. The healing of the ulcer is permanent. We have never seen a recurrence of ulcers after this type of treatment. Impressed by immediate and permanent results, the professor of dermatology at our university regularly referred to us all cases of varicose ulcers for operative treatment.

THE SULFONAMIDES AS AN ADJUNCT TO THE TREATMENT OF COMPOUND FRACTURES

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IN 1932 before the Clinical Congress of the American College of Surgeons in St. Louis, I presented a survey of 304 compound fractures of the long bones and their treatment by débridement, Carrel-Dakin technique, and open reduction with plating when indicated. Since then the advent of the sulfa drugs has made advisable a change in the treatment of compound fractures if the case and environment is suitable, and the fracture is seen within a few hours following injury. The importance of the role played by débridement and the sulfonamides has not been accurately established. Caldwell asserts that "the most desirable feature of the drug is obtained through absorption into the blood stream which from the wound reaches its peak in 12 to 18 hours and is then ably supplanted by oral administration. Diebert states, "The administration of the sulfonamide group by mouth is relatively unimportant. Keys states that fractures compounded from within, compound fractures produced by rifle or pistol bullets are usually not infected and débridement of such wounds is not necessary. Hook states that "internal fixation and closure of compound wounds is safe in many hands in civil practice but such treatment is strongly discouraged in war surgery. All of the gas gangrene reported following the attack on Oahu occurred in wounds that were primarily closed. Wilson whose experience with the sulfonamides in compound fractures has mostly been in the war areas, states that compound fractures incurred under war conditions may be most safely treated by the sulfonamides and the open pack method.

In a large industrial area such as this, with the facilities offered by long and well organized medical and nursing care both in the emergency hospitals in the plants and also in the general hospitals in the city and with heavy industry presenting to us a high percentage of patients with severe compound fractures, we should be able to evaluate correctly each of the constituents which go to make up the proper care of these patients. The factors involved in the correct plan of treatment of such injuries are as follows:

1 Early and thorough débridement done by a competent conscientious and painstaking surgeon

2 Reduction of the fracture with fixation of the fragments by means of internal splints if necessary

3 The use of the sulfonamides as an adjunct in the treatment of these compound wounds.

Briefly the outline of treatment is as follows

1 *Débridement* A thorough débridement within 18 hours is still the most essential factor in the treatment of compound fractures. This can not be overemphasized the elimination of dirt, crushed and devitalized tissues foreign bodies bone fragments without blood supply is most necessary as the first and most important item in the treatment of these injuries. No amount of sulfonamide or any other kind of drug can take care of a wound left in a dirty condition. The importance of this procedure is shown by the fact that some surgeons have been satisfied to close compound fractures after a débridement done to their satisfaction even before the use of the sulfa drugs.

2 *Reduction of the fracture.* Following débridement the fracture is reduced and no hesitation is felt in applying internal fixation in the shape of plates or screws if it is believed that such will more firmly immobilize the fracture and thus promote union. If internal fixation is unnecessary splints are applied or if the fracture is badly comminuted skeletal traction may be necessary to reduce the fragments satisfactorily

3 *Sulfonamides* The use of sulfanilamide, sulfathiazole, or a mixture of the powder and crystals locally has been carried out in each wound though it was our opinion that its distribution throughout the wound had only a minor influence on the successful outcome of these cases. Two to 5 grams of the drug however were spread evenly throughout the wound with care that no lumps were formed that might act as irritating foreign bodies and extrude through the wound at a later date. All wounds were closed without drainage.

Wounds will be met with which are extensively crushed and torn and consequently are swollen and edematous so that primary closure is impossible. These should be carefully débrided the

Carrel-Dakin treatment instituted high elevation of the limb carried out, and the swelling having subsided in 8 to 10 days, secondary closure may be possible. But to attempt complete closure of a swollen engorged limb is to court disaster in the form of infection or gangrene. Extreme swelling is rarely met, however in the early hours after injury and therefore this procedure is rarely necessary.

The patient having received his initial dose of the drug through the wound the second dose of 30 grains of sulfathiazole by mouth is given as soon as he recovers from the anesthetic since pentothal was used in all cases they were usually able to take and retain the drug 8 to 12 hours after operation, and this dosage was given every 4 hours for 2 days. The dosage was then cut in half for 3 days following which 45 grains daily was given until the end of the 8th day when the drug was discontinued. Very little attention was paid to the blood concentration as results just as satisfactory were obtained when the concentration was 3 to 5 milligrams as when the concentration was 10 milligrams per 100 cubic centimeters of blood.

The future treatment of the fracture was carried on in the usual manner. The patient was carefully watched for any unusual temperature reaction the wound would have been widely opened and the Carrel-Dakin technique instituted on the slightest indication of any infection.

In this series, compound fractures of the fingers, toes, and skull were not included, though their progress was quite satisfactory under treatment by this method. There also were a few cases of fracture of the long bones in which the compound wound was small usually of the puncture variety, and on admission these were carefully debrided and closed. They were given sulfa drugs by mouth but if open reduction was required to correct the alignment it was done 7 to 10 days later following our customary method of treatment of a simple fracture. In other words, these cases were transformed into simple fractures and, therefore, their inclusion in this series would only be confusing. In all, 48 compound fractures were treated in 36 individuals: they included fractures of the femur, 1 fracture of radius, 12 fractures of ulna, 10 fractures of tibia, 9 fractures of tarsals and metatarsals, 15 and 1 compound fracture-dislocation of the tarsal bones treated at the Children's Hospital of Pittsburgh.

The acid test of this method came in those cases in which an open reduction was carried out and for proper fixation a foreign material, screw, nail or plate, was applied to the bone and the wound

closed over it. There were 14 of these cases. We know that with the molybdenum stainless steel plates and screws the oxidation taking place in the body is far less than with the vanadium or any other metal previously used yet this factor alone cannot account for the fact that only one plate had to be subsequently removed and this for the reason that it was loose and no sign of infection or oxidation was found at the time of removal.

The benefits of this method of treatment were real and satisfactory.

1. It was possible to close every wound without drainage.

2. Osteitis or osteomyelitis did not develop in any case.

3. Owing to the primary closure of the wound, skin grafting was unnecessary in any case.

4. In fractures near the joints with the wound closed much earlier and fuller motion could be obtained than in those with the wound open.

5. Dressings of the wound with the consequent contamination which sometimes occurs in open wounds and the loss of valuable time of trained workers was cut to a minimum by the elimination of the open wound.

6. In only one case was a second operation necessary to remove the steel plate. In a previous series by the Carrel-Dakin method, the plate was removed in 68 per cent of the cases.

We are faced with the assertions of experienced competent men such as Hook and Wilson, that the closure of compound fractures has no place in war surgery. On the other hand packing these compound wounds wide open with various materials does not always lead to the happiest conclusions, even with the Carrel-Dakin method osteomyelitis or osteitis developed in 15 per cent of the cases. To anyone familiar with the treatment of compound fractures this is a tragedy necessitating prolonged disability and frequent operations. Through air transport (3) of the wounded in the service and the giving of plasma en route thousands of severe casualties arrive at modern base hospitals well within an 18 hour period from the time of injury. Well trained surgical personnel is present and the picture is an exact counterpart of that met with in civil life. A distinction cannot therefore be made in the methods of treatment and, should clean surgery done early by competent hands plus sulfa therapy and primary closure of the compound fracture prove more efficient than the open pack method in a wider range of cases, than I have here presented then undoubtedly this treatment could be carried out in various theaters of war much to the advantage of the injured man.

In conclusion may I again emphasize that this is a procedure which should be carried out only by the trained surgeon of large experience by one able to realize the seriousness of a compound fracture and its prolonged disabling qualities if not properly treated by one sufficiently conscientious and capable of doing a thorough débride-ment and with a sufficiently developed sense of judgment to open a wound widely if he believes infection is present

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A CLINICAL AND LABORATORY EVALUATION OF THE ACTION OF SULFONAMIDE OINTMENTS

JOHN R. COCHRAN M.D. Chicago, Illinois

HARDLY a day passes that one does not read some new testimony praising the superior qualities of sulfonamides when used locally on burns, open wounds, compound fractures, skin infections. Every drug store, most busy doctors' offices, and dispensaries in hospitals and industry alike use sulfonamides suspended in various ointment bases. The literature and the experience in thousands of cases reported seem almost overwhelmingly in agreement that sulfonamide ointments, used locally are a real contribution to surgery (3, 5, 8).

The purpose of this article is to report certain clinical and laboratory observations which cast serious doubt on the efficacy of the average sulfonamide ointment.

In 1939 we first started using sulfonamides locally in ointment form. It will be remembered that powdered sulfanilamide was not commercially available at that time. Ointments containing sulfonamides had not, as yet, appeared on the market. Searching for some more effective agent for the treatment of indolent varicose ulcers of the leg we prepared our own ointment by grinding sulfanilamide tablets in a pharmacist's mortar and mixing this powder in sterile vaseline. It should be noted that at this time we also adopted the principle of applying all such dressings with elastic pressure.

Shortly thereafter the literature began to give repeated confirmation of our own observations that the ulcers seemed to do better with ointments containing sulfonamides than they had with any other form of local ambulatory treatment. There was a good percentage of cases, however, which failed to do well with sulfonamide ointment therapy.

It was not until 1941 that we began seriously to question the value of the ointments which we had been using. By this time we were using ointments prepared by the pharmaceutical manufacturers. During that year we began a series of controlled clinical experiments for the purpose of evaluating various methods of treating burns. At that time we were also conducting controlled experiments

to evaluate the effectiveness of tyrothricin (to be reported elsewhere). In both these experiments controls were set up on each patient so that one area was treated with sulfonamide ointment and another similar injured area was treated with sterile vaseline, tyrothricin etc. It became obvious that the areas treated with sulfonamide ointments showed clinical infection and positive cultures as often as the control areas treated with sterile vaseline. In fact it appeared that the areas treated with sterile vaseline healed more rapidly in many cases.

This observation in the clinic led us to a laboratory evaluation of the sulfonamide ointment itself. The particular one we were using at that time was a 5 per cent sulfathiazole ointment in a so called aquaphor base. The laboratory tests we devised were simple, but seemed to us to simulate the contact between ointment and the wound surface. We first suspended a weighed amount of the given ointment in a test tube of normal salt solution and then agitated the mixture. The tube was placed in an incubator at 37 degrees centigrade for 24 hours and was agitated occasionally. At the end of the 24 hour period the chemist made an analysis by the colorimetric method for sulfathiazole in solution. Quite to our surprise we found that there was almost no sulfathiazole in solution. The laboratory reported "a trace," or less than 1 milligram per cent.

Because of this striking result the experiment was repeated with the ointment mentioned and then with a representative sample of most of the commercial ointments available on the market. These ointments were variously described as being in aquaphor base, vaseline, water miscible base, water washable base. The laboratory report in each case was identical. None of the ointments by this method of evaluation liberated any appreciable amount of the drug into the saline.

We then attempted to simulate more accurately the burned surface of a patient by repeating the experiments using human plasma. We also attempted to titrate the amount of free sulfonamide in solution on the burned surface of a patient who had had sulfonamide ointment applied 24 hours previously. The latter method did not give satisfactory results. Gurd, Ackman, and Wilson (5)

From the Division of Surgery, Northwestern University Medical School, and the surgical service of Drs. H. E. Jones and S. W. McArthur St. Luke's Hospital, Chicago, Illinois.

have performed this experiment to their satisfaction, and results will be reported later in this paper.

Our experiments performed by agitating ointment in human plasma agreed almost exactly with the results in saline, i.e. none of the commercial ointments tested liberated any appreciable amount of sulfonamide drug into the plasma during 24 hours.

Blood concentration tests performed on patients who had had sulfonamide ointment applied to burns almost routinely showed a trace only of sulfonamide in the blood stream. (We now believe, from work with a more satisfactory ointment which liberates large amounts of sulfa drugs, that the failure to show any appreciable blood concentration is not the result of the failure of the sulfa drug to go into a solution. It probably results from the well known fact that a burned surface, during the first few days, does not absorb chemicals placed upon it to any appreciable extent.) The observation that blood stream concentration is minimal when sulfonamide ointments are used locally has been confirmed by others, both in burns and on intact skin (1, 3, 8).

In studying the composition of the ointments we had evaluated it appeared that the commercial ointments examined at the beginning of 1943 consisted of a suspension of sulfonamides in some more or less oily base. It is well known that a drug suspended in the oily phase stays in that oily phase when water is brought in contact with the ointment (7). One would hardly expect, therefore, that the sulfonamides would be liberated from the oily phase of the ointment when applied locally. If one used an oily base ointment, some additional agent, such as an emulsifying or wetting agent, would have to be added to alter the suspension in such a way that the drug would be liberated into the aqueous phase.

About this time our attention was drawn to the work of Gurd, Ackman, Wilson, and others at the Montreal General Hospital, which appeared to give the answer to an oily base which would still liberate sulfonamides (1, 2, 5). They incorporated a wetting agent Triethanolamine in a water and oil mixture. They showed conclusively that the addition of a wetting agent resulted in the liberation of amounts of sulfonamides which approximated the maximum solubility of sulfathiazole in water. We then repeated the laboratory tests we had devised using the Montreal General Hospital preparation, and discovered the following:

The Montreal General Hospital emulsion mixes very readily with water, saline, or plasma, whereas

the usual ointment, even after 24 hours, still is separate from the liquid phase. The Montreal General Hospital emulsion liberates large amounts of the sulfonamide used. When we mixed the Montreal General Hospital sulfathiazole emulsion in saline for 24 hours we were able to recover 40 per cent of the sulfathiazole from the emulsion. Repeating the experiment, using plasma, we recovered 47 milligrams from an original weighed amount of emulsion containing 50 milligrams of sulfathiazole (84 per cent).

Our results indicate a higher solubility of sulfathiazole in the emulsion than the known solubility of sulfathiazole in water (4). It has been shown (5) that sulfathiazole is about 800 times more soluble in the emulsion than it is in water. This solubility undoubtedly results from the use of triethanolamine.

As a result of the tests described we adopted the Montreal General Hospital emulsion as our standard form of sulfathiazole ointment therapy. We obtained samples of this emulsion from the Vogel Laboratories, made according to the Montreal General Hospital formula. We also attempted to duplicate the emulsion described in our own pharmacy. Both the preparations seemed much too liquid. It was very difficult to apply this rather watery emulsion to burned surfaces.

For this reason we have modified somewhat the Montreal General Hospital emulsion and the emulsion is now made at the St. Luke's pharmacy according to the formula and directions as follows:

The original Montreal General Hospital emulsion was made on a weight volume basis, according to the following formula:

	Per cent		Per cent
Sulfathiazole	5	White beeswax	5
Triethanolamine	5	Liquid paraffin	64
Distilled water	84		

Mr. Louis Gdalan at the St. Luke's Pharmacy makes the ointment on the weight-weight basis according to the following formula:

	Per cent		Per cent
Sulfathiazole	5	White beeswax	7.5
Triethanolamine	5	Heavy mineral oil	6.5
Distilled water	84		

In making the ointment, the sulfathiazole, triethanolamine and distilled water are mixed cold. The wax is gently melted, the mineral oil added to the melted wax and this mixture allowed to cool. The oily mixture is then added to the water mixture with constant whipping. With some experience a smooth, creamy ointment results which has a pleasing odor like vanishing cream. Sterile sulfathiazole crystals, sterile water and oil are used in the preparation of the ointment. Bacteriological tests have shown the ointment to be sterile. This ointment should not be sterilized by heating, since heat will crack the emulsion.

From the practical standpoint of application, the Montreal General Hospital emulsion is most satisfactory. It goes on readily, does not soil clothing or dressings and has considerable anesthetic action. Gurd, Ackman, and Wilson attribute the latter to the sulfathiazole (5).

SUMMARY AND CONCLUSIONS

Clinical as well as laboratory work demonstrates that the majority of present day sulfonamide ointments are inert, liberating inconsequential amounts of sulfonamides. Whatever value they possess is contained in the ointment base and not in the sulfonamide. An effective ointment is described, originally elaborated at

the Montreal General Hospital, which liberates large amounts of sulfonamides.

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EDITORIALS

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ORGANIZATION OF THE RED ARMY MEDICAL CORPS

A GREAT deal has been written in the lay press about the excellent results of the treatment of war injuries by the surgeons in the Soviet Union. Perhaps as a result of the lay reporter's tendency to embellish the telling of surgical facts the impression is rather widespread that Russian surgical practice and technique are far advanced beyond that practiced in the United States or Great Britain. As a matter of fact there is much to be admired in Russian surgery, but the surgical principles recognized by well trained surgeons of whatever country they may be remain essentially the same. The technique of applying those principles differs between countries, clinics and men but taken as a whole the character of graduate surgical training in the United States has produced in the last twenty five years a generation of surgeons whose technical ability is difficult to surpass. The Surgeon General of the United States Army has said it is these

men and not adjuvant methods of treatment who are responsible for the high quality of the results obtained in the treatment of the casualties which have occurred in World War II.

Very little attention has been paid to other accomplishments of Soviet surgeons and this is true particularly in the field of military medical organization for the care of the wounded. Diagrams of the medical organization in the Red Army have been published but to see it in practice serves to emphasize its vertical character. The Surgeon General of the Red Army, Yefim Ivanovich Smurnov, who is 38 years of age, is responsible directly to the Peoples Commissariat for Defense and the Chief of Staff of the Army. There is no intermediary organization between him and the Chief of Staff and this direct relationship enables him to be entirely aware of the nature, purpose and magnitude of each offensive before it is launched. His responsibility is to provide adequate medical care, equipment and hospitalization for anticipated casualties. Under his direct supervision the ranking medical officers of his corps assigned to the air ground and support forces carry out the policies of medical or surgical treatment laid down by him. Wounded airmen are treated in the same hospitals and by the same surgeons as are injured infantrymen. A compound fractured femur received by a pilot or gunner is treated according to the same surgical principles and under the same environment as one received by an infantryman as the result of an exploding ground mine. There is no apparent need in the Red Army Medical Corps to have a separate group of doctors, hospitals and nurses for the treatment of the air force per

sonnel. While the medical organization within an Army must be under the command of the general of that Army for tactical combat purposes the policies of surgical treatment are uniform and are under the control of the Surgeon General. In name and in fact, then, Smirnov is the Surgeon General of the Red Army and the resulting unity of action in the care of the wounded is therefore speedy and effective.

Of course such an organization of a medical corps is not new. Until General Order No. 31 was issued on February 18, 1918, the relationship of the Chief Surgeon of the American Expeditionary Force in World War I to the General Staff and the chiefs of the Administrative Staffs was similar to that which existed between the Surgeon General's Office, the General Staff, and the several bureaus of the War Department situated in Washington. Both were identical in relationship to that which now exists between the Surgeon General of the Red Army and its General Staff. But on that date and during the middle of a war the Chief Surgeon was given a dual rôle in the Services of Supply and as an advisor to the General Staff, but he was situated at the headquarters of the Services of Supply. It became obvious almost immediately that this order made the Chief Surgeon's Office merely an agency for the procurement and distribution of supplies and personnel and had the effect of separating him both physically and functionally from the activities of the Zone of Operations. It became evident also that the Medical Department was handicapped in its extensive and complex operations by being cut off from direct access to the Chief of Staff by a line of command. This transfer of the Chief Surgeon's office in the American Expeditionary Force to the Services of Supply was effective for the procurement of supplies and the construction of

hospitals but according to a letter written on March 15, 1918, by the Chief Surgeon, it resulted in disconnection of his office from the medical administration of the front. It was impossible for the Chief Surgeon to meet his responsibility for the conduct of medical affairs in the combat zone and caused relations with the combat forces virtually to cease.

The Chief Surgeon of the American Expeditionary Force at that time made a strenuous written presentation of his views. He said in various memoranda:

"The present organization in the American Expeditionary Forces places a line officer of the General Staff in position to pass upon or present for higher consideration all matters of fundamental policy affecting the Medical Department. He can nullify the most carefully worked out program having for its object Medical Department efficiency.

Again: "In providing the necessary medical supplies for an army only one of the comparatively unimportant functions of the Medical Department has been fulfilled. The demands made upon the Medical Department by combat activities cannot be satisfied if the prevailing conception of that department as a supply department is adhered to.

Following World War I this organization of the Surgeon General's Office under the Services of Supply or Army Service Force was continued. During peace time the classification of the Medical Department among the supply services was emphasized to the detriment of the equally or more important staff function. The subordinate position of the Surgeon General necessitates the approval of nonmedical line officers of the Army Service Forces before purely technical medical regulations can be put into effect. For example, the Surgeon General had long desired to authorize and direct immunization against tetanus. This

matter was held up for more than a year pending the approval of line officers and was cleared barely in time to protect our present Army against this infection.

Another of the results of this type of organization has been the gradual development of a medical corps in the Air Force based on the erroneous assumption that injuries received from combat in the air require separate hospitals and staffs for their treatment. It is well recognized that there has been and is now a strong and vigorous campaign for an Air Force Medical Corps quite separate and distinct from the Medical Department of the Army.

Much the same situation exists in regard to medical facilities in connection with the ground forces. Each Army has its surgeon whose policies of treatment cannot be influenced by direct command from the Chief Surgeon of a theatre of operations. In fact in the United States surgical consultants for Service Commands are unable to examine casualties which have been sent to an Evacuation Hospital situated in the area of that Command but on maneuvers with the Army to which it was attached until permission is obtained through the line of command. In a theatre of operations the activities of the consultants to the surgeon of the theatre are confined to station and general hospitals directly under his command. Consequently an Army or an Air Force may have consultants duplicating in number and function those attached to the staff of the Theatre Surgeon. There are therefore air force ground force and service force chief surgeons independent in practice but on paper the first two subordinate to the latter who has the title of Surgeon General of the U S Army or Chief Surgeon of a Theatre of Operations, as the case may be. On the surface it would appear that even more confusion has been added by the appointment of

a Chief Medical Officer to the Supreme Headquarters of the Allied Expeditionary Forces.

The position of the Medical Department and the Surgeon General in the Staff organization of the Army makes it incumbent upon the Surgeon General to have an enormous reservoir of supplies equipment and doctors to meet any demand which may be made upon him without an opportunity for him to be acquainted with the details of a planned campaign or battle. That such a situation must inevitably lead to inactivity of doctors while they wait for their removal from the supply shelf for use and that it is natural to overstock for fear of being short of the demand at any given time is obvious. To say the least it is an extravagant use of doctors which is more serious than the overstocking of supplies or equipment.

In all fairness it must be said that as a group civilian surgeons were not interested in the affairs of the Medical Corps of the U S Army in the 25 years intervening between World Wars I and II. They universally recognized the errors in organization of the Medical Department committed in World War I but upon their return home they were anxious to forget the tribulations of war and eager to resume their professional lives. The civilian surgical organizations made no attempt to learn of the problems and plans of the Medical Department in case of war though a few surgeons who had participated in World War I had shown an individual interest to help which was consistently rebuffed. Yet the civilian doctors have had to shoulder the load of work during this war with a nucleus of less than 2000 Army doctors, who as a group adopt a defensive attitude of passive resistance toward the newly commissioned medical officer.

Finally any criticism of the attitude of the Medical Department toward postgraduate

surgical training medical educational policies, insistence upon the adoption of measures which might prevent certain injuries of war or the extravagant use of doctors in the Army should not be directed at the Surgeon General

of the U S Army or his staff The fault lies the fundamental anomalous relation of his office to the General Staff and the Army as whole which can be corrected only by the War Department.

LOYAL DAVIS

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

IN his book *The Foot* Norman C. Lake deals with disorders injuries wounds, infections and vascular disease of the foot. The fact that this is the third edition of the book published since 1935 indicates that it has found wide recognition from those interested in disorders of the foot. A careful review of its contents leaves the impression that its popularity is justified.

The section dealing with the evolution of the foot, the influence which evolutionary changes have had upon the production of foot disorders and the development of the foot is excellent and the deductions made are sound if not final. Although most worthwhile, the material on evolution and development is perhaps too exhaustive for a book of this type since it comprises about 10 per cent of the entire subject matter. The same criticism may be made of the section on footwear which includes an interesting but not particularly informative historical chapter.

The discussion of foot disorders in general is thorough and informative. However the material dealing with fractures and wounds of the foot and congenital club foot is not impressive and leaves much to be desired. It is questionable whether such a superficial discussion of these subjects as is given has any place in a book of this type which is primarily concerned with static and circulatory foot conditions. On the other hand, the discussion of vasospastic lesions trench foot, frostbite, and immersion foot is particularly good and is based on the latest information to be had on these subjects all are covered in a most complete and interesting manner.

Mr Lake has written a scholarly book in which the contributing and exciting causes of foot disorders are thoroughly covered, and the pathology of the various subjects completely and lucidly discussed. Its chief weakness from the point of view of the clinician lies in its lack of definite recommendations for treatment a tendency to rely upon and advise conservative measures which are only palliative and rarely prove satisfactory and a failure to provide a section dealing adequately with the surgical operations which are useful in correcting foot pathology and give satisfactory and permanent results.

On the whole, this book is decidedly worthwhile, and its reading will repay anyone who is interested in the treatment of foot disorders.

FRANK D. DICKSON

(The Foot. By Norman C. Lake, M.D., M.S., D.Sc. (London) F.R.C.S. (Eng.) 3rd ed. Baltimore: The Williams & Wilkins Co. 1945

AS the book *Traumatic Injuries of the Facial Bones* is a new departure in method of presentation direct quotations from it may be most descriptive.

The plan of this book has been based on many requests from officers of the armed forces who have been assigned to the Mayo Foundation for training in maxillofacial surgery. These officers have urged Dr. Ench and Dr. Austin to publish their demonstrations of methods of dealing with fractures of the bones of the face. In doing so the authors have given proper emphasis to the fact that many facial injuries involve structures in the repair of which the dental surgeon may well be concerned.

The material is a collection of procedures which at the Mayo Clinic, have given the most satisfactory results with the fewest complications.

This book is divided 'not only into chapters but also into individual problems under each of which the management of specific types of injuries of the facial bones is considered.' The problems are divided into comments and detailed discussions with reading material opposite the illustrations.

The reader will find considerable repetition. This is intentional to stress those items which deserve emphasis. Moreover this volume was not designed to be read necessarily from cover to cover. Instead it has been prepared as a handbook in a manner that, we hope will enable the reader to obtain the essential information concerning each problem without perusal of an entire chapter or the complete book."

The basis of most of the illustrations are moulages by Dr. A. H. Bulbulian that have been familiar in exhibits at medical meetings. On these moulages have been mounted the various appliances recommended.

As it is the definite task of the authors in presenting their own material the reader may be spared making comparisons with any divergent ideas or methods. The authors are generally conservative and though at first glance the procedures may seem complicated, the number of them is actually limited. There have been so many varieties of apparatus and so many methods proposed for fixation that priorities are difficult to establish and the authors have perhaps made easier reading by not calling attention to the history and development of every fundamental. The addition of clinical photographs and results would be of great value but collection of

Traumatic Injuries of Facial Bones, an Atlas of Treatment By John B. Ench, M.S., D.D.S., M.D., and Louis T. Austin, D.D.S., F.A.C.D. in collaboration with Bureau of Medicine and Surgery U.S.N. by Philadelphia and London W. B. Saunders Co.

there would be a colossal task and would add much to the length of the volume.

The presentation is straightforward, the editing is excellent, and the book will be gladly received by all who are interested in the work it describes.

JAMES BARRETT O'NEAL

THE third edition of *Clinical Laboratory Methods and Diagnosis*, which first appeared in 1935, has been partially rewritten, and so much material on newer laboratory tests and interpretations has been added that it is printed in 2 volumes totaling 2130 pages. A 100 page complete index is added in each volume, a feature which greatly enhances the usefulness of this encyclopedic work.

All fields of laboratory work are treated with in formal arrangement of clinical manifestations of disease related laboratory procedures in complete detail, the interpretations of the results, author comments, and bibliography. In many chapters aspects of particular interest are elaborated, controversial evidence is presented, and illustrative case histories are given. In addition to adequate and detailed discussion of the usual clinical laboratory tests, there are included chapters on postmortem examinations, tissue cutting and staining, preparation of museum specimens, toxicologic technique, detection of crime by laboratory methods, and minimal supplies, equipment and reagents for pathologic laboratories.

These two volumes bring together a great mass of information of general medical, as well as of special technical, interest. The previous editions have had general acceptance. The present greatly enlarged edition will be found of value as a laboratory guide, general medical treatise and a ready reference for many esoteric subjects related to laboratory practice and not usually found in laboratory manuals.

JOHN C. MCCARTER

IN *An Atlas of Anatomy*, consisting of 183 pages and 235 illustrations, 5 pages are allotted to the head and neck, 43 to the thorax, and 33 to the vertebral and vertebral column. The subject matter is well indexed, and illustrations are listed.

Volume 1 has the same general appearance as Volume 2. Clarity without cluttering is achieved by judicious placing of the illustrations on the page. Simplification in labeling plus meticulous accuracy of the plates all enhance the teaching value of this book. Depth or 3rd dimension is constantly emphasized. For example plates 286 and 87 on the right and left sides of the mediastinum, respectively, not only are artistically beautiful but also are anatomical treasures. They show the thoracic cage with its muscles and bones, the diaphragm, pleura and lungs, sympathetic trunks, phrenic and vagus nerves.

Clinical Laboratory Methods and Diagnosis: A Textbook on Laboratory Procedures With Their Interpretations. By J. B. H. Grubb, M.D. D. B. 3rd ed. Vol. 1 and 2. London: The C.V. Mosby Co. 1944.

An Atlas of Anatomy in Two Volumes. By J. C. Baugh, Grant, M.C. M.B. Ch.B. J.M.C.S. (Edin.) Vol. Vertebral and Vertebral Column, Thorax, Head, and Neck. Baltimore: The Williams and Wilkins Co. 1943.

arteries and veins, bronchi and major blood vessels all easily visualized with perfect later-relationship.

Mastery of anatomic detail is made possible to the student only by carefully planned dissections. There are four plates on the posterior triangle of neck. These start with the superficial structures and end with the brachial plexus and subclavian vessels illustrating surgical anatomy as it is encountered either in the dissecting room or operating amphitheater. The dissections of the skull are also novel and valuable. For example, the interior of the base of the skull illustration 361 shows both temporal bones removed, but the heads of the mandible are *in situ*. This plate makes it possible to see the base of the skull and still look through it. Specialties are not neglected. The pharynx, palate, teeth, nose, ear and eye are included.

The one possible criticism rests in the arrangement of the plates. It was somewhat disconcerting to find the posterior triangle separated from the anterior triangle of the neck by illustrations of the skull, mid-brain and eye.

By utilizing original, well planned dissections and remarkable clarity in his photographic plates, Grant has prepared an atlas which will simplify and facilitate the teaching of surgical anatomy.

SAMUEL J. FOSTERLOW

IN the foreword to the book *The Permeability of Natural Membranes*, Professor Harvey points out that organisms could not have evolved without relatively impermeable membranes to surround the cell constituents. And again, no one can fail to be impressed with the great differences in properties of living and dead cells. The dead are completely permeable to diffusible substances, while the living retain one material and pass another. Around this theme Dr. Davson and Dr. Danielli have built a book of 12 chapters (36 pages) in which they have assembled and critically analyzed existing data of vital importance to the cell physiologist, the neurologist, and the clinician who seeks a mechanistic answer to problems of cell permeability, absorption and secretion, and changes in ion distribution accompanying nerve conduction and muscle contraction.

Methods employed in measuring ionic equilibrium are discussed and the necessary mathematical formulation given. The nature of the plasma membrane of the erythrocyte is explained. It is thought to consist of a lipid film, few molecules in thickness, to which is absorbed polypeptide chains of protein oriented with respect to polar and nonpolar groups. The structural solidity is postulated as possibly being due to crosslinked meshwork of the polypeptide chains resulting from the unfolding of the adsorbed protein molecules on the cell surface. Such a structure might account for the sieve-like properties observed in some cell membranes. Studies

The Permeability of Natural Membranes. By Hugh Davson, D.Sc. and James Barbara Danielli, D.Sc. A.I.C. With foreword by E. M. R. Harvey. Cambridge University Press, New York: The Macmillan Co. 1943.

concerning the permeability of the erythrocyte are most complete.

Even the casual reader cannot help but retain certain facts which contrast with his usually accepted opinions. To mention but two instances the "chloride shift" usually associated with the name of Hamburger was discovered by Nasse in 1878. The second point concerns the phenomenon in 1891 content of the erythrocyte. In man rabbit, monkey pig and some other species the potassium or sodium concentration is approximately 100 millimols per 1000 grams sodium being 16 millimols or less. In the erythrocyte of the dog and cat, however, conditions are reversed, the sodium concentration is 107 and 104 millimols per 1000 grams for the respective species with a potassium concentration of 9 millimols or less.

Electrical phenomena associated with ionic distribution across a membrane are amply demonstrated during the passage of an impulse in a nerve, or contraction in a muscle the resting potential falls. This seems to be associated with a transitory change in membrane permeability permitting a leak of K^+ from the membrane cells.

Hemolysis is discussed from the standpoint of hypotonicity and lysis. Hypotonic hemolysis may result in (a) the cell being ruptured into a number of fragments or (b) the cell membrane stretched so that existing pores are enlarged sufficiently to allow the passage of hemoglobin or (c) the cell membrane breaks with one or more large holes appearing. From electrical impedance studies of ghosts evidence favors the third alternative.

The chapter on secretion considers among other things the phosphorylation of glucose during absorption from the intestine or from the glomerular filtrate by the proximal convoluted tubule of the kidney. In either case the mechanism postulates that glucose passing into the cell membrane is converted to the glucose-phosphate ester which can not diffuse back through the membrane of the cell by which it entered. It then passes through a second membrane into body fluids being again converted to sugar by an enzyme associated with this cell. The diagrams amply illustrate the discussion. The secretion of glucose requires energy all substances which, on penetration into a cell are easily synthesized into a substance whose rate of back diffusion through the cell membrane is less than that of the original substance.

The chapter on the kidney summarizes the modern concepts of glomerular filtration and tubular reabsorption. The evidence for tubular secretion of phenol and creatinine in man is cited. Varying tubular activity in other species is discussed.

This book presents a wealth of material in a very able manner. The literature is critically evaluated and opinions which in the authors' judgments are inadequately supported by fact, are followed with finality. An extensive bibliography, disposed of most chapters. The appearance of this book is timely and should facilitate research in one of the most important mental fields of physiology.

CHARLES J. FARM

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

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- PRINCIPLES AND PRACTICE OF LYMPHATICAL THERAPY. By Alvan L. Barach, M.D. Philadelphia, London, Montreal J. B. Lippincott Company, 1944.
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- CATARACT AND ANOMALIES OF THE LENS GROWTH, STRUCTURE, COMPOSITION METABOLISM, DISORDERS AND TREATMENT OF THE CRYSTALLINE LENS. By John G.

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PERFORATING ABDOMINAL INJURIES

With Special Reference to Reduction in Mortality
By the Use of Transfusions and Sulfonamides

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WORLD War II has again focused attention on abdominal injuries. In World War I for the first time abdominal injuries were treated by exploration whenever possible. During this period and the decades following the war a considerable literature arose on the treatment of such wounds. The principles of their operative treatment have not changed materially since they were developed in World War I. The results even in recent series of cases are strikingly similar to those published in 1916. Wallace reported a study of 1,000 cases of gunshot wounds of the abdomen in the British Expeditionary Force. The mortality of 965 operative cases was 53.9 per cent which was only a little lower than the total mortality of 60.2 per cent. Lockwood, Kennedy and their associates found a mortality of 51.9 per cent in 356 operative cases reported in 1917. Fraser and Drummond presenting 313 penetrating wounds of the abdomen at the same time reported 173 recoveries, a mortality of 55.2 per cent.

A number of excellent articles reporting abdominal injuries in civil life have appeared in the past 10 years. A review of the reported mortalities is interesting in that they are but slightly lower than the statistics for World War I. In 1924 Condit reported a mortality of 45 per cent in 70 abdominal gunshot wounds and a mortality of 28 per cent in 32 stab wounds. Billings and Walking reported 220 penetrating abdominal wounds in 1931, found in operative cases 48.2 per cent mortality in gunshot wounds and 22 per cent mortality in stab wounds. Martin in 1933 reported a mortality of 46.6 per cent in 180 cases of penetrating abdominal wounds in only 123 of which had there been perforations of viscera. Prev and Foster treated 2 gunshot wounds of the abdomen with a mortality of 68 per cent. A mortality of 21 per cent in 100 stab wounds and 59.3 per cent in 64 gunshot wounds of the abdomen was reported by McGowan in 1935. A year later Oberhelman and Le Count reported on 343 cases of gunshot wounds in the Cook County Hospital with a mortality of 61.4 per cent. Taylor in 1938 reported a mortality of 59.8 per cent in 87 patients found to have gunshot wounds penetrating the abdominal cavity. Rippey's series of 337 cases of perforating gunshot wounds of the abdomen which had been explored had a mortality of 60.5 per cent. In a

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small series of 35 gunshot wounds and 11 stab wounds Storck was able to report mortalities of 40 per cent and 27.2 per cent respectively. Recently Hamilton and Duncan have reported an operative mortality of 48.9 per cent in 182 cases of gunshot wounds and 13.8 per cent in 145 abdominal stab wounds. Elkin and Ward in an excellent report, found a mortality of 46.4 per cent in 181 patients with abdominal rifle or pistol wounds explored on the surgical service of Emory University Hospital. Zininger briefly mentions 46 penetrating abdominal wounds treated recently at the Cincinnati General Hospital with a mortality of a little less than 11 per cent.

Thus the mortality for gunshot wounds of the abdomen operated on has remained about 50 per cent. This is very similar to the statistics compiled on the battlefields in the last war although obviously there were many more cases on the battlefield which did not come to operation.

Since the beginning of World War II two interesting papers have appeared. Gordon Taylor has reported at length on the abdominal injuries occurring at Dunkirk and during the bombing of Britain. He summarized this material by stating that approximately 50 per cent of patients with abdominal injuries, for whom operation is possible survive. Ogilvie in a most interesting report on experiences in Africa reported a mortality of 47.5 per cent in 316 cases of abdominal injury in which a viscus was damaged. In a second series which had not yet been analyzed 247 patients were treated with the astonishing mortality of 34 per cent.

Again and again it has been emphasized that shock and infection are responsible for the great majority of deaths in abdominal injuries (3 6 8 11 12 17 19). In the past 5 years the sulfonamides have come into general use in the treatment of infections, and during this same period the use of blood and blood substitutes in the therapy of shock has received tremendous impetus from the development of blood banks. If these therapeutic measures are of value in the treatment of abdominal injuries their worth should be reflected in the lowered mortality of such injuries during the past 5 years.

Between 1915 and 1943 146 perforating abdominal wounds were explored by the resident staff of the Johns Hopkins Hospital. Of these patients, 87 were treated between 1925 and 1938 and 59 between 1939 and 1943. Any perforating abdominal wound in which a viscus or a major retroperitoneal structure was injured has been considered as a perforating injury. Penetrating wounds in which the peritoneal cavity was entered but in which no viscus was injured have been excluded. Patients moribund on admission on whom exploration could not be undertaken have also been excluded. Included in the series was 1 patient who died from aspiration of stomach contents during the induction of anesthesia.

The patients in this series were for the most part young healthy Negro males and females. Stab wounds were commonly inflicted with the so called switch blade. Gunshot wounds were usually caused by 32 or 38 caliber revolvers. There were a few rifle wounds and but one shotgun wound. Approximately 88 per cent of the patients were operated on within 3 hours of the time of injury.

The operative treatment of abdominal injuries in the Johns Hopkins Hospital did not change materially in the period covered by this series of cases. All the patients were operated upon by the resident staff. Any patient strongly suspected of having a penetrating abdominal injury was subjected to operation whether objective evidence of an intra abdominal injury was present or not. The measures for treating shock current at the particular period were employed preoperatively. A systematic exploration of the abdominal cavity was carried out through a rectus incision the anesthetic agent employed was generally ether. Perforations of hollow viscera were closed whenever possible. Resection of intestine was employed when the extent of the injury precluded simple closure. Injuries to the large bowel were treated in the same way as injuries to the small bowel and no attempt was made to exteriorize perforations of the colon. Injuries to the liver were packed or were sutured. In 8 instances of injury to the spleen splenectomy was carried out twice. Injuries to the kidney were treated conservatively. These operative principles are

similar to those so well described in the many contributions to the subject (13 15 18 21)

ANALYSIS OF CASES

The 146 cases of perforating abdominal injuries explored at the Johns Hopkins Hospital between 1925 and 1943 consisted of 91 gunshot wounds and 55 stab wounds. Between 1925 and 1938 there were 87 perforating abdominal injuries of which 56 were gunshot wounds and 31 stab wounds. Between 1939 and 1943 there were 59 such injuries 35 of which were gunshot wounds and 24 stab wounds. Table I lists the structures injured in these cases. In many instances several organs were damaged or a single viscus such as the small intestine received multiple injuries

fection not accurately located. In 2 instances ileus was the chief cause of death. In 1 patient a gastric fistula and subdiaphragmatic abscess contributed to death. Another died during induction of anesthesia from aspiration of stomach contents. A single patient died from postoperative gastric hemorrhage. Thus in 11 cases death was due primarily to shock and in 11 cases to infection.

In contrast to this of the 6 deaths occurring between 1939 and 1943 5 were due to shock and one was probably due to complications arising from a paraplegia. None of the deaths could be attributed to infection alone.

Prior to 1939 8 transfusions were administered at operation one of which was an autotransfusion. In the past 5 years 30 patients have received transfusions of blood or plasma or both before operation or at operation. The number of postoperative transfusions increased similarly. One patient who succumbed from shock due to uncontrollable bleeding from pelvic vessels received more than 7000 cubic centimeters of citrated blood. Another patient who survived received 3000 cubic centimeters of blood and 500 cubic centimeters of plasma at operation with a transfusion immediately after operation. At the present time a patient arriving in the accident room in a state of shock is immediately given plasma and is matched for transfusion. Unless it is felt that there is continued active intra-abdominal bleeding transfusions are given rapidly until the patient recovers from shock. If the patient does not respond to multiple transfusions and it is felt that there is active intra-abdominal bleeding exploration is carried out after a continuous transfusion is started.

In the past 5 years the use of sulfonamides has become an almost routine treatment of patients with perforating abdominal injuries. During this period 46 patients received a sulfonamide in some form. The drug employed and the mode of administration have varied as advances in the use of sulfonamides have been made and new drugs have been added. It is not possible in this small series of cases to compare the efficacy of different methods of sulfonamide administration. At present 10 grams of sterile sulfanilamide usually is ad-

TABLE I.—STRUCTURES INJURED

Small intestine	52
Large intestine	45
Stomach	44
Liver	39
Mesentery	17
Spleen (splenectomies)	8
Kidney (nephrectomy)	4
Great vessels	4
Biliary tract	3
Duodenum	3
Pancreas	1
Bladder	1

sections of small intestine with 3 deaths.

Among the 87 cases explored from 1925 to 1938 there were 27 deaths a mortality of 31 per cent. The mortality in the 31 stab wounds was 25.8 per cent and in the 56 gunshot wounds 33.9 per cent. Between 1939 and 1943 there were 6 deaths in 59 cases a mortality of 10.1 per cent. The mortality in the 24 stab wounds was 4.2 per cent that in the 35 gunshot wounds was 14.3 per cent. The mortality for the total 146 cases was 22.6 per cent.

TABLE II.—MORTALITIES

	1925-38		1939-43	
	Per cent	Cases	Per cent	Cases
Stab wounds	25.8	31	4.2	24
Gunshot wounds	33.9	56	14.3	35
Total	31	87	10.1	59

Analysis of the causes of death in the first group of cases showed 11 deaths due to shock 4 deaths due to peritonitis and 5 due chiefly to pneumonia. Two patients died with an in-

in the abdominal cavity and wound of exploration. Sulfadiazine or sulfamerazine is administered after operation by mouth or parenterally.

The number of postoperative complications in the patients who recovered was not materially different in the two groups of cases (Table III) their severity however was decreased. There were relatively the same number of wound infections and instances of pneumonia in each group of cases.

TABLE III.—POSTOPERATIVE COMPLICATIONS
IN PATIENTS WHO RECOVERED

	1939-43	
	NO.	%
Wound infection	20	5
Pneumonia	8	7
Pneumonia and lung abscess		
Pleural effusion		
Empyema	3	
Hemopneumothorax	3	6
Obstruction (immediate or later)	7	4
Wound dehiscence		
Fecal fistula	4	
Subphrenic abscess		
Peritonitis		
Liver abscess		
Gas gangrene		
Arteriovenous fist. in liver		
Thrombophlebitis		
Embol.		
Pedicle urinary fistula and bladder tumor.		
Delirium tremens		
Head injury and postoperative psychosis		

In several infected wounds there was at least partial wound dehiscence.

OBSERVATIONS FROM STUDY

This group of 146 perforating abdominal wounds represents a relatively uniform series of cases. The injuries were inflicted for the most part on young healthy patients who were subjected to operation within 3 hours of the time of injury. The operative technique in the hands of the resident staff remained essentially unchanged. The striking reduction in mortality in the years 1939 to 1943 from a previous mortality of 31 per cent to 10.1 per cent certainly can be attributed chiefly to the use of transfusions and sulfonamides. Improvements in anesthesia and the use of constant gastric suction or the Miller Abbott tube must be considered in this reduction in mortality but they would seem to have had only a small share in the reduction in mortality. Between 1925 and 1938 ileus

was the chief cause of death in 2 instances and certainly contributed to other deaths. Aspiration of stomach contents during induction of anesthesia also caused 1 death. No deaths between 1939 and 1943 could be attributed either to ileus or to anesthesia.

The relative value of transfusions and sulfonamides in these cases is difficult to estimate. It is probable that the use of blood and blood substitutes has had a greater influence in the reduction in mortality than the use of sulfonamides, despite the fact that most of the deaths in recent years have been due to shock rather than to infection. It has been noted that patients in shock are more susceptible to infection (3, 8). The improved postoperative condition of patients in the past 5 years with the use of transfusions must have played a large part in their resistance to infection. Lona (9) however has recently emphasized the value of sulfonamides for such patients.

In the perforating abdominal injuries operated on in the past 5 years death has been due largely to hemorrhage which could not be controlled at operation or to injury so severe that massive transfusions had little effect on the patient's state of shock.

The results reviewed here, of patients treated individually with all the resources of a large hospital represent a goal unattainable by the military surgeon. The relative simplicity of the wounds, early operation and concentrated care before and after operation make the mortality figures presented here far lower than those which could ever be obtained on the battlefield. However this small group of cases does show clearly that the use of transfusions and sulfonamides can effectively reduce the mortality of perforating abdominal wounds.

SUMMARY

1. A total of 146 cases of perforating abdominal injuries were explored at the Johns Hopkins Hospital by the resident staff between 1925 and 1943 with a mortality of 22.6 per cent.

2. In the period 1925 to 1938 the mortality was 31 per cent in 87 cases. This was reduced between 1939 and 1943 to 10.1 per cent in 59 cases.

3 The striking reduction in mortality is due to the frequent use of transfusions and the customary practice of administering sulfonamides.

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THE LATE CONDITION OF NERVE HOMOGRAFTS IN MAN

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OF all the problems connected with the surgical repair of nerve injuries none is more pressing than that presented by the large gap in a main nerve trunk

Where end-to-end suture is impossible the only rational alternative is some form of nerve graft¹ but, if this is agreed there is still uncertainty as to the types of graft which can be employed with some prospect of success. Enough experimental and clinical evidence has accumulated to show that autografts of small caliber are far superior to all others. (Sanders, 1942 Seddon Young and Holmes, 1942 unpublished results of one of us—H J S.—in 16 cases operated on between 1940 and 1943) Indeed in rabbits, functional recovery after autografting of the lateral popliteal nerve is as good as that seen after section and immediate suture (Gutmann and Sanders, 1942) Yet even if improvements in technique lead to the establishment of autografting as a valuable operation, the proportion of large gaps that can be dealt with by this means must always be small. In many cases the extent of the lesion and the diameter of the damaged nerve are such that the patient cannot himself provide the material required to fill the gap. In a patient who has suffered amputation of a limb as well as an extensive nerve lesion it may be possible to remove a nerve from the stump and to use it as a graft or if there are lesions of great longitudinal extent in two nerve trunks, a segment of the less important nerve may be used to bridge the gap in the other (Seddon unpublished work) But cases of this kind are exceptional and usually autografting can be carried out only if a length of cutaneous nerve sufficient to allow the construction of a bridge across the gap can be taken without great inconvenience to the patient.

This leads to consideration of the alternatives homografts and heterografts, either of which may be used fresh after storage or preserved by fixation. In spite of all claims to the contrary the only material which on critical examination gives any prospect of success is the homograft either fresh or stored (Sanders 1942 Gutmann and Sanders, 1942) There is no longer any doubt that, in a variety of animals, homografts may provide a bridge for regeneration of a number of fibers sufficient to give not merely measurable but useful functional recovery. Nevertheless there are discouraging reports of partial necrosis in some experiments (Merzbacher 1905 Ingebrigtsen, 1915 Eden 1919) and Sanders and Young (1942) noted a cellular infiltration around and within their homografts, which must indicate that the graft causes a persistent reaction on the part of the host tissue. When stored homografts are used the state of affairs may be even more unsatisfactory. In one of Eden's experiments, where a 5 centimeter gap in the sciatic nerve of a dog had been bridged by a homograft stored for 3 days in physiological saline solution it was found that after 120 days the graft had been largely replaced by fibrous tissue only a few patches of degenerate nerve tissue remaining regenerating axons from the proximal stump of the host nerve had succeeded in penetrating only a very short distance into the graft.

The results of homografting in man are most discouraging. Although Sanders review suggests that there were 8 successes in 42 cases reported by 8 authors, careful scrutiny of the data fails to reveal any convincing evidence of recovery except in 3 of Duell's (1934) 6 cases of facial nerve homografting. In these the transplanted nerve was, of course much smaller than in the average transplantation for a nerve injury in a limb and the gap to be bridged was quite short. (The case reports examined were those of Albert, 1878 Ward 1890 Robson 1896 Sherren 1906 Bethe 1916 von Enderlen and Lobenhoffer 1917

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Sanders (1942) has reviewed this subject so thoroughly that referral of the literature is unnecessary here.

Foerster 1917 Spitzzy 1917 Dujarier and
François 1918 Eden 1919 Delagenière
1924 and Duel, 1934)

It is curious to find that in spite of these dismal experiences no one except Eden thought it worth while to remove an unsuccessful homograft for histological examination. In 1 case a fresh homograft was removed and examined 9 months after implantation. At first sight the graft appeared to be in the very early stages of Wallerian degeneration the axons being somewhat fragmented and the myelin still present as globules. But there were no Schwann cells although the thick connective tissue strands between the tubes were full of nuclei (These findings were confirmed by Spielmeyer who examined the same material independently.) In a second case a segment of nerve from an amputated limb was transplanted to a position in the subcutaneous tissue of another patient. The graft was removed after 38 days and similar changes were found. Eden concluded that the nervous elements in a homograft undergo a slow necrosis and are gradually replaced by connective tissue some of it arising from the graft itself the rest by proliferation of fibroblasts of the host tissues. Whether this is the invariable fate of homografts in man has yet to be proved and it is on these grounds that our cases are reported.

Storage of grafts is obviously technically desirable and grafts have been left for varying periods at temperatures ranging from 0 to 37 degrees C in normal saline or Ringer's solution (Tello 1914 Ingebrigsten 1915 Eden 1919 Sanders and Young 1942) in vaseline or petrolatum (Dujarier and François 1918 Huber 1920) or dehydrated and frozen (Weiss and Taylor 1943). Since Gutmann and Sanders (1942) found that the cellular reaction was less and the functional result slightly better after the use of homografts stored in Ringer's solution in the refrigerator than after the employment of fresh homografts it was decided that this method of storage would be employed should the occasion arise.

MATERIAL

Four cases were treated by homografting in 2 fresh homografts were used and in 2

stored grafts. In 3 cases the grafts were removed later when it was evident that no recovery was to be expected. The patients were dealt with at the Oxford Nerve Injuries Centre (Wingfield Morris Hospital) and the Highet R B Zachary and H J Seddon. The operations were performed by the late W B suture materials used were Case 1 human hair Cases 2 and 3 fine silk and Case 4 stainless steel wire. The final operations (excision of graft) were performed with a view to determining the prospects of recovery before proceeding to the reconstructive operations required for the treatment of permanent paralysis. It is hardly necessary to describe the reconstructive operations that were carried out.

The early histories of Cases 1 and 2 have already been described in detail as part of a series of traction injuries of the lateral popliteal nerve (Highet and Holmes 1943). The purpose of this paper is to describe the late condition of the homograft in the 3 cases in which re-exploration was performed.

HISTOLOGICAL TECHNIQUES

The techniques employed were directed towards demonstrating myelinated and non myelinated nerve fibers using a modified Weigert and a silver-on the slide method respectively in addition the usual routine stains were employed. All the material was examined in paraffin sections it may be useful to other investigators of similar human homografts to note that these grafts were so densely collagenized as to have much the consistency of tendon hence simple paraffin embedding should for choice be avoided and replaced by methods designed for the treatment of particularly hard tissues.

CASE REPORTS

CASE 1 (B 20) A soldier born 1918, December 1 1940 he fell down a flight of steps and suffered an adduction injury of the right knee with avulsion of the head of the fibula and a severe traction lesion of the lateral popliteal nerve. On June 3 1941 he was admitted to the Wingfield-Morris Hospital, at which time he had complete lateral popliteal paralysis. On June 18 1941 the damaged segment of nerve, 11.5 centimeters in length, was resected and suture was carried out with the knee flexed to an angle of 120 degrees.

On January 23, 1942 re-exploration because of absence of signs of recovery. It appeared that the postoperative stretching had produced another traction lesion of even greater severity than that for which the first operation had been performed. Two small biopsy specimens taken from the nerve trunk showed nothing but fibrous tissue presenting an appearance like that of tendon.

March 11, 1942 (eight and a half months after nerve suture) resection of the fibrotic zone, which was 19 centimeters in length, was done. The gap was bridged with a homograft, removed 30 minutes previously from a freshly amputated leg. The condition for which the amputation was performed was sarcoma of the tibia and the lateral popliteal nerve was used, with the result that a very good fit was obtained. The blood group of the donor was O that of the recipient B.

April 2, 1942 soldier returned home wearing a toe raising spring.

October 5, 1942 a firm cord was palpable in the line of the lateral popliteal nerve from above the knee joint to below the head of the fibula. It was not tender and neither pressure nor percussion over the nerve gave any sensations referable to its distribution. No signs of recovery were noted, although ample time had been allowed for regeneration—573 days for 20 centimeters, the distance between the upper suture line and the nearest muscle, tibialis anterior.

November 19, 1942 operations were done as follows: (1) exploration and removal of lateral popliteal homograft, (2) tenodesis of tibialis anterior and peroneal foot-drop.

The state of the nerve and of the gr. ft.

The proximal trunk had a diameter 10 by 7 millimeters, consistency normal, it ended in a neuroma 20 millimeters long and with a diameter of 13 by 8 millimeters, of much the same consistency as the nerve.

(3) The graft appeared remarkably healthy and shelled out of its bed very easily except at the suture lines where it was moderately adherent (Fig. 1). The diameter of the proximal 7 centimeters, 8 by 7 millimeters slightly firmer than normal. Below 7 centimeters it split into two parts (see Fig. 2): a large lateral strand 3 by 6 millimeters in diameter and a small medial strand diameter 2 by 3 millimeters, consisting of three bundles. This part of the graft was soft and felt empty. At the lower suture line the strands united again and joined the peripheral stump which divided almost immediately into the anterior tibial and musculocutaneous divisions.

Closer inspection of the graft showed that the bundles were easily visible, particularly in the distal part where it was soft; here the sheath was very thin. It was difficult to be certain of its color because of slight persistent oozing from the surrounding tissues, but the nerve looked very like a tendon that had lost its normal sheen,—it had lost the characteristic cream tinge of normal nerve.

Electrical stimulation was entirely negative. The whole of the graft with the adjoining central and peripheral stumps was excised.

Histological appearance. The graft was grossly abnormal in structure, the nervous tissue within it having been replaced almost completely by dense masses of mature collagen. At many points remains of the original nerve bundles were to be seen. In some of these the general architecture was still preserved but the fibers were necrotic and acellular (Fig. 3). In others the bundles had been invaded by phagocytes, and their nervous tissue partly or completely replaced by collagen (Fig. 3).

This graft, which had been left in place longer than those in Cases 3 and 4, may be taken as showing the later stages in the replacement of a homotransplant: it was almost completely converted into a cable of fibrous tissue entirely devoid of regenerating nerve fibers at any point and incapable of receiving them.

CASE 2 (M 24) R.A.F. officer born 1908. September 26, 1940, he suffered a violent adduction injury of the left knee while playing a game called "high-cock-a-forum." On June 30, 1941 he was admitted to the Wingfield Military Hospital. Lateral popliteal paralysis was present and there was no evidence of recovery. On July 6, 1941 suture of lateral popliteal nerve which was found to be completely ruptured, both stumps showing considerable intraneural damage. Gap after resection back to satisfactory bundles in both stumps was 25 centimeters. Suture was done with knee flexed 130 degrees and hip in hyperextension. Since, after 8 months, there was no recovery after this suture which lay just above the head of the fibula, it was decided to re-explore the nerve, and this was done on March 5, 1942. As in the last case it was found that the postoperative stretching had produced a severe traction lesion so extensive that 25 centimeters of completely fibrotic nerve had to be removed before obvious bundles were reached. The gap was bridged with homograft (the medial popliteal nerve) 6 centimeters long, removed from a leg amputated 14 days previously for osteogenic sarcoma of the tibia and stored in Ringer's solution in an ice-box in the interval. Blood group of donor A. Blood group of recipient unfortunately not determined. April 10, 1942 discharged.

When examined exactly 1 year later there was no evidence of recovery that could not be attributed to circumferential overlap. Later in the same year it was learned that this officer had been killed in an accident on October 4, 1943, so there is no information about what recovery if any occurred between March and October. But there was no clinical evidence after 365 days that any fibers had reached the most proximal muscle, the tibialis anterior lying 21 centimeters from the proximal suture line.

CASE 3 (B 36) A soldier born 1914 November 12 1941 he suffered a fracture of the right humerus with a most unusual combination of nerve lesions there was incomplete radial paralysis complete paralysis of biceps and brachialis but no loss of sensibility in the cutaneous distribution of the musculocutaneous nerve and complete median paralysis. March 11 1942, he was admitted to the Wingfield Morris Hospital. March 25 1942, exploration of median nerve and bridging of gap by a homograft.

The lesion was a remarkable one. The proximal trunk of the median nerve terminated in a large neuroma whose lower extremity was 2 centimeters below the junction of the roots of the nerve. This neuroma was connected by a fine strand of tissue about 1 millimeter in diameter and 13 centimeters long with the distal trunk, which ended proximally in a conical glioma. Direct repair was out of the question especially as the gap after resection back to satisfactory bundles was 19 centimeters in all. The gap was bridged with a homograft the lateral popliteal nerve removed from a leg amputated 14 days previously for osteogenic sarcoma of the tibia, and stored in Ringer's solution in an ice box, in the interval. Blood group of donor O blood group of recipient O.

May 24, 1943 no sign of recovery the distance between the proximal suture line and the nearest muscle pronator teres, was 27.5 centimeters and this muscle was still paralyzed after 425 days. It was, however possible that regeneration was proceeding very slowly and it was, therefore, decided to explore the nerve under local anesthesia with a view to detecting sensory fibers by direct electrical stimulation. The operation was carried out on the following day.

The state of the nerve and of the graft

There was dense scar tissue surrounding the whole track of the graft, but particularly at its upper and



Fig. 1. Case 1. Appearance of the graft 573 days after implantation. Proximal end on right.

lower ends. It appeared that the graft itself was not adherent to the scar though the subsequent histological examination suggests that the line of cleavage was rather artificial. The central and peripheral stumps presented no unusual features (Fig. 4) but the graft had shrunk from 19 to 12 centimeters in length and from 7 to 2.5 millimeters in diameter except at its extremities where it gradually broadened out until it blended with the central and peripheral stumps. It was impossible to estimate the consistency of such a fine strand with any certainty.

Electrical stimulation was entirely negative and as it was obvious that the graft had almost disappeared it was excised without hesitation.

Histological appearances. Examination of transverse sections of the graft at various levels showed that the great shrinkage which it had undergone was due to removal of nerve substance and not to a shrinkage of the tissue elements themselves. Thus at several levels the specimen had a diameter of only 2 by 1 millimeter and it contained only one nerve bundle, 1 by 1 millimeter in diameter. This remaining nerve bundle was not in any way shrunken (Fig. 5). It contained a large number of nerve fibers

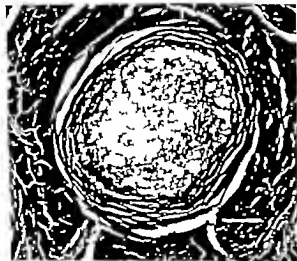


Fig. 2. Case 1. A completely necrotic nerve bundle. Masson. Scale = 100 μ .

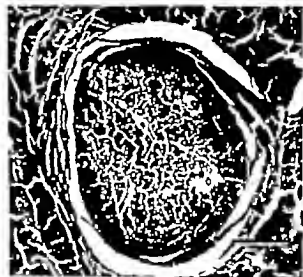


Fig. 3. Case 1. A nerve bundle which has been transformed into a mass of collagen. Masson. Scale = 100 μ .



Fig. 4. Case 3. Appearance of the graft 4-5 days after implantation. Its diameter has decreased by about two-thirds.

which retained their general normal architecture (Fig. 6) but were completely necrotic, being devoid of nuclei of any kind and abnormal staining reactions. At several levels in the graft these areas of preserved necrotic fibers were bounded by zones of active phagocytosis, in which the necrotic fibers were in the process of destruction; the regions in which this process was complete were filled with dense masses of collagen (Figs. 5 and 6).

At the extreme ends of the graft its replacement was still farther advanced; the specimen consisted entirely of dense fibrous tissue containing only a few minute fibrotic nerve bundles (Fig. 7).

In this case, therefore, the grafted nerve did not survive, and the donor nervous tissue was in the process of replacement by a mass of collagen fibers. This replacement was furthest

advanced at the ends of the specimen, and the great shrinkage in the middle of the graft was due to the fact that only one nerve bundle remained; the collagen which had replaced the rest of the nerve was presumably adherent to the host tissues and was dissected away during operative exposure.

CASE 4 (B. 46). A school-boy born 939, September 25, 1914, boy received injury to left arm while out rabbit shooting; there was extensive loss of tissue in the lower half of the medial aspect of the arm. The wound was treated without delay and healing was expedited by skin grafting. Some days after the injury it was noticed that there was some involvement of the median and ulnar nerves.

On June 9, 1942, he was admitted to the Wingfield Morris Hospital. He had a deep irregular scar on

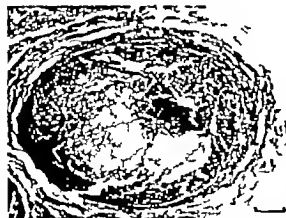


Fig. 5. Case 3. Transverse section of the middle of the graft; only one nerve bundle is present; it contains some of necrotic nerve fibers (left) and some of phagocytosis and collagen replacement (right). Mason. Scale = 100 μ .



Fig. 6. Detail of part of the graft showing condition similar to that in Figure 5. Mason. Scale = 100 μ .

the medial side of the arm 11 centimeters long by 6 centimeters broad ending 2 centimeters above the medial epicondyle. Healing had been complete since November 1941. There was complete ulnar paralysis. Median nerve all forearm muscles acted strongly though there was no response to galvanic or faradic stimulation paralysis of intrinsic muscles of the thumb anesthesia of median distribution but some sweating in the palm and analgesia only in the anhidrotic patches. No further details will be given about the median nerve since they are hardly relevant.

June 17 1942 exploration of median and ulnar nerves was carried out, homograft used to bridge the gap in the latter. There was a gap in the ulnar of 11.5 centimeters. This was reduced to 8 centimeters by anterior transposition of the distal stump and sacrifice of the branches to the long flexors but as a total resection length of 3 centimeters was required for exposure of healthy bundles proximally and distally the gap to be bridged even with the elbow flexed at 90 degrees was about 11 centimeters.

It happened that a long strand of the medial cutaneous nerve of the forearm diameter 2 by 3 millimeters was available in a case undergoing operation in an adjoining theater and this was used to bridge the gap. At the suture lines the bed for the nerve was satisfactory but in the intervening zone the muscle beneath and the overlying subcutaneous tissues were both densely scarred. Blood group of donor O of recipient A.

June 1943. Although insufficient time had elapsed for clinical manifestations of recovery (the branches to the long flexor muscles having been sacrificed) it was decided to re-explore the nerve in view of the disquieting state of affairs found in Case 3 and the manifestly unsatisfactory dimensions of the graft, which was much too small in diameter.



Fig. 7. Case 3. Transverse section of the graft immediately below the proximal suture line. Only one tiny fibrous nerve bundle remains the rest is fibrous tissue. Masson. Scale = 400 μ .

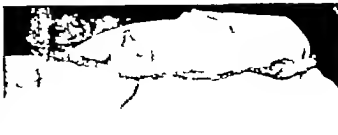


Fig. 8. Case 4. Appearance of the graft 371 days after implantation.

June 23 1943 exploration of ulnar nerve and resection of graft were done. The dissection was difficult on account of scarring.

The state of the nerve and of the graft

The central stump ended in a hard neuroma and there was a soft glioma on the peripheral stump. The graft was of about the same length as at the time of insertion namely 12 centimeters, but its diameter was reduced by about one half (Fig. 8). In view of this shrinkage it was decided that the graft was serving no useful purpose and it was removed together with the adjoining central and peripheral stumps.

Histological appearances. The longitudinal sections of the proximal suture line showed that as the macroscopic appearances suggested the host nerve terminated in a bulbous neuroma containing nerve fibers of all sizes. The grafted nerve was closely apposed to the end of this neuroma and at its proximal end some apparently normal nerve bundles contained numerous regenerating nerve fibers in these bundles the Schwann cells were proliferated and over the proximal 5 millimeters of the graft they had the usual appearance of nervous tissue which has undergone Wallerian degeneration and is in the process of reinnervation (Fig. 9). But around and within these bundles masses of lymphocytes were seen and large numbers of dilated blood vessels and vessels devoid of corpuscles which may have been lymphatics these signs of chronic inflammation could hardly have been due to the suture material used since they were quite remote from it.

At a level about 8 millimeters below the suture line the graft bundles began to show even more marked abnormalities of structure and contained very few regenerating fibers. And at 25 millimeters below the suture line they had lost all trace of normal nerve tube structure and were composed only of dense masses of collagen in which a few abnormally shaped cells perhaps phagocytes were scattered. No identifiable Schwann cells were present, and the interfascicular connective tissue contained masses of lymphocytes and some multinucleated giant cells. And in the middle of the graft there was only a trace of even the general appearance of nervous structure, for the specimen was chiefly composed of a mass of scar tissue (Fig. 10). Great abnormalities were visible throughout the distal half of the graft. Some nerve bundles contained masses of phagocytes in process of removing the remains of the original nerve



Fig. 9. Case 4. Longitudinal section of nerve bundle in the graft immediately below the proximal suture line. It contains normal proliferated Schwann cells, but there is intense local lymphocytic reaction and myelinated vesicles around and within the bundle. (Mason, Scale = 100 μ)

fibers and others contained only masses of poorly cleaved collagen (Figs. 4 and 5). These abnormalities became less marked in distal nerve. It was approached but here also there were the signs of an intense chronic inflammatory reaction.

Thus although the nervous structure of the graft was reasonably well preserved over a

length of a few millimeters at its extremities and had been invaded by regenerating axons, an intense inflammatory reaction had been provoked and most of the transplanted nerve was in the process of phagocytic destruction and collagen replacement.

OBSERVATIONS

Three of these homografts were unqualified failures and there is little reason to suppose that success might have been achieved in Case 2 but for the patient's untimely death. In Case 3 the graft had been stored for 14 days in Ringer's solution and in some respects the histological changes found within it differed from those in Cases 1 and 4 in which a fresh transplant was used. The stored graft seemed completely dead like a sequestrum of bone or muscle and was in process of removal exactly as if it were a foreign body when inspected 426 days after implantation its diameter had been reduced by more than one half yet there was no shrinkage of the bundles that remained; the graft had been eaten away. On the other hand in Cases 1 and 4 there appeared to be a progressive interstitial phagocytosis and replacement of the graft tissues by



Fig. 10. Case 4. Transverse section near the middle of the graft. Only a few small and abnormal bundles remain; the rest have been replaced by collagen. (van Geeson, Scale = 500 μ)



Fig. 11. Case 4. Longitudinal section toward the distal end of the graft. One bundle shows phagocytic removal of the graft nerve fibers, and in the other collagen replacement is complete. A mass of lymphocytes lies in the inter-fascicular connective tissue. (Mason, Scale = 100 μ)

collagen. This difference in behavior may not be significant but it certainly shows that storage of homografts which is actually beneficial in rabbit experiments has no advantage in surgical practice. It also indicates that Wallerian degeneration does not proceed normally in a graft of this size during the period of storage.

There is, therefore, a most disturbing contrast between the state of these homografts and that described in rabbits (Sanders and Young 1942; Gutmann and Sanders 1942). For although the rabbit homografts were invaded by macrophages and lymphocytes in a manner never seen in autografts, reinnervation proceeded in a more or less orderly fashion. In the late stages the only significant abnormalities were a few patches of fibrosis and a deficiency of larger fibers. Functional recovery though poorer than after autografting was good enough to be useful. What factors then might account for the failure in our cases and the relative success in animal experiment?

1. *Blood group compatibility.* The discovery of blood groups has been a powerful stimulus to the study of homologous tissue compatibility in general though it has too readily been assumed that there is some connection between red blood cell compatibility and compatibility of tissues with nucleated cells. The nature of the problem as it concerns skin grafting has been discussed by Medawar (1943) who reached the tentative conclusion

that the failure of skin homografts is unrelated to blood groups; the evidence brought forward by Gibson and Medawar (1943) suggested rather that the failure is due to the development of an *active acquired immunity*.

And in corneal grafting which in recent years has been conspicuously successful the blood groups of donor and recipient are irrelevant (Duke Elder 1938).

Therefore one is bound to consider the possibility that the failure of nerve homografts in our series of cases and in those recorded in the literature was due to the acquisition by the host tissues of an active immunity to the grafted nerve tissue. If this is so, then the success of homografts in the rabbit, and the recovery in Duels 3 cases of facial nerve homograft might be due to the small size of the transplant. The outgrowing host nerve fibers, perhaps accompanied by their own Schwann cells, could traverse the nerve tubes of the graft and reach the peripheral stump before the destructive reaction was developed.

However there is not as yet sufficient evidence to lead to the conclusion that blood group compatibility is irrelevant to the problem of nerve homografting. In Duels 3 cases the blood groups of donor and recipient were the same and there is no record in the literature of any series of cases in which the correlation between blood-grouping and the success or failure of the graft is made. In the



Figs. 12 and 13. Detail of the two nerve bundles shown in Figure 11. Masson. Scale = 100 μ .

present state of our knowledge surgeons who intend to use nerve homografts should no doubt group recipient and donor so that decisive evidence may be forthcoming. But unless some method is discovered for storing grafts without diminishing the prospects of a take (our single experience is not encouraging) the chances of getting a graft from a donor of the same blood group as the recipient will be very remote since they depend on the coincidence of a nerve exploration requiring a graft with an amputation for an uninfected lesion neither very common occurrences in patients of the same blood group. If blood groups matter then storage is essential.

2 *The thickness of the graft.* It has been suggested here that the success of small homografts in animals and man may be due to the fact that satisfactory innervation can take place before an immunity reaction develops in the host tissues. If this is so then the failure of large grafts in man is due to their length and perhaps to some extent to their mass as related to the total mass of the body. But a simpler explanation may be that the failure is due to inadequate vascularization of the graft. If this is the case then a cable homograft having a better chance of rapid vascularization would be more successful than a graft having the full thickness of a main nerve trunk. In 3 of our cases (2 examined histologically) the grafts were from main nerve trunks and it is conceivable that there was a delay, a fatal one in their vascularization. However in Case 4 in which the graft was from a subcutaneous nerve an equally depressing state of affairs was found though it must be conceded that here the bed was a poor one. Yet if the large grafts necrosed centrally as a result of delayed vascularization it would be expected that the more peripheral bundles would survive. This was not the case and failure of blood supply can hardly be held responsible for the destruction of the graft.

3 *The state of the suture lines.* Although the state of the suture lines is of supreme importance the most satisfactory union is of no avail if the substance of the graft undergoes unfavorable changes. In our cases the approximations obtained at the grafting opera-

tion were as good as those performed in the average end-to-end suture the macroscopic appearances at the later explorations and the histological findings showed that there had been no rupture of the suture line or other accident.

Our short series of cases does not yield sufficient evidence for an analysis of the nature of the process responsible for the destruction of the nerve homografts. The fate of the stored graft might be simply described as that of an implanted foreign body but the replacement of the fresh homografts is a more obscure process. A remarkable feature is the preservation of the general macroscopic structure of the graft in spite of the profound internal changes which it has undergone. This preservation might be taken to suggest that it is the fibroblasts of the transplant itself which proliferate in the process of collagenous replacement though it would seem more reasonable to suggest that they are cells of host origin. Eden as heretofore stated, temporized by suggesting that cells of both types took part in the process.

But there is no doubt that the reaction at least in its end result is very different from that found in rabbits or cats (Bentley and Hill 1936) though the difference may be one of degree rather than of kind. The results of animal experiment have been not uninformative so much as actually misleading and the proper study of homografts, so far as clinical surgery is concerned must be in man. The difficulty of the problem is that of collecting evidence assuming that further clinical trials are worth while (and there is little to encourage us in this belief) the factors governing success or failure could hardly be discovered without numerous biopsies, to which even the most co-operative patient could not possibly be asked to submit. Experiments on large animals might perhaps, bring us reasonably near to a final answer.

SUMMARY

1 Although the results of nerve homografting in small animals are not discouraging there is evidence that the implanted tissue almost invariably provokes a cellular reaction

which since it may lead to more or less collagenization within and around the graft must be regarded as unfavorable

2 In man there are apparently only 3 recorded successes after homografting and in each case the facial a very small nerve was repaired There is so far only 1 published record of the late appearances of a human nerve homograft it had become completely converted into a strand of fibrous tissue (Eden)

3 Four cases of human homografts are reported in this paper all of them failures and in 3 the remains of the graft were examined at 371 425 and 573 days respectively In 2 cases in which fresh grafts were used the bulk of the graft had become collagenous to such an extent that almost nothing remained of the original nerve elements and there was clearly no sign or even possibility of regeneration through this long core of fibrous tissue In the case in which the graft used had been stored for 14 days in Ringer's solution the tissue was completely dead and was in process of removal by phagocytosis

4 The following possible causes of failure are discussed (a) Blood group incompatibility an unproved and improbable factor (b) The development of a specific tissue immunity such as seems to be responsible for the destruction of skin homografts Where the gap to be bridged is short as in rabbit experiments the reaction may not occur until after fibers have reached the peripheral stump on the other hand in man the gap to be bridged is always a long one and it may well be that an immune reaction attains its greatest intensity long before the fibers have

had time to traverse the graft (c) Failure of vascularization almost certainly of no significance

5 Thus although the available evidence is not great it all tends to show that nerve homografting as a means of closing large gaps is an unsound procedure

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THE ESTIMATION OF AREAS OF BURNS

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ALTHOUGH the proportionate area of skin burned has long been recognized as useful as a guide to the prognosis of burns, the proportionate area has now become of even greater importance as a guide to treatment. One of the first needs of a patient with a serious burn is adequate plasma therapy. After a close estimate of the size of the area of the burn and of its proportion to the total area of skin has been made the

First aid Formula (5) can be used to estimate the approximate amount of plasma needed during the first day of treatment. The exact amount to be given should, however, be guided by repeated tests of the hemoglobin, hematocrit or red blood count and of the plasma protein and other chemical tests of the blood.

Long prior to its use for this purpose Weidenfeld and Berkow made studies directed to simplifying the recording of and comparison of burns. Both studied by actual measurement the surface areas of the parts and of the whole surface of many individuals of all ages. As a result of this work in this country and in Great Britain Berkow table 1 constantly in use in studies of burns. Both Weidenfeld and Berkow pointed out that surface proportions varied widely between birth and adult life. Seeger and Wallace also pointed out this fact but other important publications that have stressed the use of Berkow's table have mentioned only his table for adults.

When in search of a suitable diagram and standards for the recording of burns in children it was seen that Berkow's tables for adults and for children which have been perfectly satisfactory for work up to date are oversimplified and contain certain errors that

should if possible be avoided in the more exact studies that are now being made in many clinics. For instance he used DuBois and DuBois (4) measurements to determine the areas of the different parts of the body and found the same values for the parts that Dultus and DuBois found. These measurements include the buttocks with the trunk but without making a counterbalancing correction in the figures. Berkow includes them with the thighs. Furthermore he set a higher value in the trunk than either DuBois and Dultus or he himself had found to be an average measurement and made the following explanation. To balance the greater seriousness of burns of the anterior surface of the trunk the third and fourth decimal places have been deducted from the average proportion of the head and extremities and added to the number expressing the proportion of the trunk. This gives the trunk a value of 38% of the body surface and of this 20% is apportioned to the anterior surface and 18% to the posterior.

LITERATURE

The literature concerning the surface area of the body consists of the two articles previously mentioned (1, 11) and many articles by authors primarily concerned with problems of the measurement of basal metabolism. Boyd has summarized this literature in a very useful manner. A difficulty arises, however in that all the data assembled for metabolism work had been collected primarily to secure a correct total area and differences in points of division between one region and another were unimportant in securing a valid total. In the use to which surface area proportions are put with burns such definitions are of great importance. Also it is of great importance to subdivide the surface into as many clearly demarcated areas as possible so as to permit the easiest possible visual comparison. A large amount of excellent information is available in Boyd's monograph to permit the divi-

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son of the body surface into 12 parts (head trunk and two each of thighs legs feet, arms and forearms and hands) The data for subdividing the upper extremity into three in stead of two parts and for separating the neck buttocks and genitalia from the trunk are less ample but sufficient for the estimation needed There are no data on the relative proportions of the anterior versus the posterior parts of the trunk

LINE OF DEMARCATION OF MAJOR REGIONS

Lines of demarcation of some regions were summarized by DuBois and DuBois (4) as follows

"Head—Lower margin of the mandible to its posterior border thence to tip of the mastoid process and in a straight line to the external occipital protuberance.

"Arm—From the acromion process anteriorly and posteriorly to the upper border of the axilla.

"Hand—Line at right angles to long axis of forearm drawn at level of tip of ulna.

"Thigh—From the perineal point going posteriorly in the natal fold to the upper border of the great trochanter thence medially in a straight line to the perineal point.

"Leg—Line at level of lower border of patella.

"Foot—Line at level of tip of lateral malleolus

These lines are strictly followed in this paper Other lines are defined as follows

1. **Neck** The line of demarcation between the neck and the trunk is the shortest line from the supraclavicular notch to the spinous process of the 7th cervical vertebra

2. **Elbow** The arm is separated from the forearm by a line drawn from the upper edge of the olecranon around to the antecubital fold.

3. **Buttocks** The lower edge of the buttocks has been defined as noted by DuBois The other edges are defined as included by a vertical line from the upper posterior corner of the trochanter to the point where it meets the crest of the ilium, then posteriorly to the midline of the sacrum and down the sacrum to the perineal point.

4. **Genitalia.** The areas defined as genitalia in the penis and scrotum in males and the labia in females the latter are considered to extend from the perineal point to the upper edge of the pubic bone.

5. **Anterior and posterior trunk** Lateral to the neck, as has been defined, the anterior and posterior halves of the trunk are divided by a line along the anterior edge of the trapezius muscle Below the axilla they are divided by a vertical line from the midaxilla

CHANGES OF PROPORTIONATE AREA OF REGIONS WITH AGE

At birth the size and area of the head is very large and the size and areas of the legs very small compared to their proportions in adult life Ample data of excellent quality are available to show the changes during the child's development It is of interest that the body and arms change their proportions very little during development After the age of 20 years further age *per se* results in no change of any magnitude to any part of the body

TABLES OF PROPORTIONATE AREAS OF PARTS OF THE BODY

Boyd has constructed a table giving the results of calculations made from the most accurate data available in the literature concerning the changes in area during growth This table divides the body into four major areas. In her publication it includes monthly data on fetuses from the third solar month to term and yearly data on living humans from 1 year to 24 years Certain items from this table are reproduced in Table I The data for newborn are from the Klein Scammon study of fetuses

TABLE I.—PERCENTAGES OF SURFACE AREA OF THE MAJOR DIVISIONS OF THE BODY ACCORDING TO BOYD*

Age	Head	Trunk†	Upper extremities	Lower extremities
	0	3	7	3
7	24	8	34	34
13	23	20	35	35
14	24	20	35	35
19	24	20	35	35
24	24	20	35	35

*Data from Boyd (1) p. 10, decimals omitted. Boyd gives the actual measurements as well as the percentages.
†Includes neck, genitalia, and buttocks

Berkow's formula for calculating the surface proportions of children is a simple one He takes his proportions for adults as a starting point. These are head 6 per cent trunk 38 per cent upper extremities, 18 per cent and lower extremities 38 per cent. For children of all ages he leaves the percentages for the trunk and upper extremities the same He adds to the head 1 per cent for each year the

age is below 12 and subtracts the same number from the figure for the lower extremities. By using this formula, Table II has been constructed.

TABLE II.—PERCENTAGES OF THE SURFACE AREA OF THE PARTS OF THE BODY ACCORDING TO BERKOW

Age	Head	Trunk	Upper extremities	Lower extremities
	18	34	18	26
	7	34	8	27
	12	34	8	21
10	8	34	8	26
5	6	34	18	24
Adult	6	32	18	28

*Includes neck and genitalia.
 †Includes buttocks.

The figures in Table II correspond exactly with those in Boyd's table in many items and partly in others. The most serious discrepancy is caused by the systematic errors introduced by Berkow which result in much too high proportions being assigned to the body and too low to the lower extremities. As Berkow states the buttocks should be included with the legs but since he used a method of measurement that did not accomplish this result 5 per cent should be added to his figures for the trunk and subtracted from the lower extremities for a proper comparison with Boyd's data. The effect on the estimated area of the trunk of making this correction results in a value of 43 per cent which is a value one-third larger than Boyd's figure at the age at which the difference is greatest (15 years) and one-quarter larger at the age with the least difference (24 years).

Boyd's table would be difficult to use in clinical studies of burns because it contains more small changes than are necessary for this type of work. Berkow's principle of keeping the same value at all ages is very useful, if too great an error can be avoided. Therefore a new table has been constructed that approaches closely to Boyd's figures at all ages above birth and avoids the extreme errors of Berkow's.

Some difficulty was encountered in making a decision as to the best figures for newborn

infants. Boyd's figures for this age are based on the data of Klein and Scammon of the surface area of fetuses. However there are records of three living newborn infants two calculated by Berkow and one by Meeh. Their measurements give slightly smaller percentages to the areas of the head and lower extremities and larger ones to the areas of the trunk and the upper extremities. For the new table, the average data of these three records were used as the chief criterion of the percentage area of the parts of newborn infants after correcting for Berkow's inclusion of the buttocks with the legs (Table III).

TABLE III.—NEW TABLE OF SURFACE PROPORTIONS FOR USE IN STUDY OF BURNS

Age	Head	Trunk	Upper extremities	Lower extremities
	19	34	19	28
	7	34	19	26
5	12	34	19	24
10	12	34	19	26
5		34	19	28
Adult	7	34	19	29

*Includes neck, genitalia, and buttocks.

DETERMINATION OF AREAS OF SUBDIVISIONS

Neck. A close estimation of the area of the neck may be made because Bradfield and Boyd both made measurements and calculations on the same subjects by two or more methods, one of which included the neck with the head and the other with the trunk. The difference in results is such that 2.4 is the area of the neck in young women, 2.0 in 16 and 17 year old girls, and 2.5 in 3 to 5 year old children. Here it will be considered to be 2 per cent.

Genitalia. From data in Boyd that are old and rather fragmentary the area of the genitalia has been stated to be from 1 to 2½ per cent. These figures are quoted without definitions. By comparison with the area of the hand it would seem reasonable to place a figure of 1 per cent for these areas.

Buttocks. There are no modern data on the buttocks as a separate area. Again by comparison with the hand it can be seen that the area of the buttocks as defined is close to 5 per cent (for the 2).

Anterior and posterior trunk After the three subdivisions mentioned are deducted there is 26 per cent of area left for the trunk. The dividing lines described separate the trunk into anterior and posterior parts that are very nearly if not exactly equal in area. Therefore 13 per cent is indicated as a suitable figure for each.

Hands A large amount of information is available concerning the area of the hands. All the data at all ages place the area of them as either exactly or very close to 5 per cent. This is a very useful figure to know in measuring burns because by using one side of one hand of the patient as an estimating device it is very simple to get an approximation of the number of times the burn is larger than this area. For this purpose the area of one side of the hand, (and closed fingers) has frequently been considered to be 1 per cent. There is no discrepancy between this value of 1 per cent and the total value of 5 per cent because the latter includes skin on the sides of the hand and between the fingers.

Forearms Much information is available for the area of the arms as a whole separate from the hands but rather less for the arms and forearms separately. However the data available are consistent and almost certainly reliable. A suitable estimate for the two forearms is 6 per cent.

Arms By subtracting the areas of the hands and forearms from that of the upper extremities given it is seen that 8 per cent is the surface of the two upper arms. This value is consistent with the measurements available.

Feet Although the areas of the lower extremities vary with age that of the feet do not. There are ample data to show that 7 per cent is the average area of the feet.

Legs As the legs vary with age it is fortunate that many measurements of the legs and thighs have been made separately. The two legs start at birth with 10 per cent of surface area. At 1 year of age there is no change. At 5 the figure is 11 per cent at 10 it is 12 per cent at 15 13 per cent and in adult life 14 per cent.

Thighs The thighs grow more rapidly than the legs. They are 11 per cent at birth 13 per cent at 1 16 per cent at 5 17 per cent at 10 18 per cent at 15 and 19 per cent in adult life.

Table IV is constructed from these data

TABLE IV —NEW TABLE OF SURFACE PROPORTIONS IN DETAIL

Age	Birth	5	10	15	Adult
Area					
Head	0	7	13	9	7
Neck					
Anterior trunk	3	3	3	13	13
Posterior trunk†	13	3	13	3	13
Buttocks	1	3	8	8	5
Genitalia					
Upper arms	8	8	8	8	8
Forearms	6	6	6	6	6
Hands	5	5	5	5	5
Thighs		12	5	7	9
Legs				3	14
Feet	7	7	7	7	7
Total	100	100	100	100	100

*Without neck or genitalia.

†Without neck or buttocks.

For use in clinical studies two charts have been constructed for recording the areas of individual cases. On the diagrams are printed the percentages of each area as visualized when the area is fixed at each age. At the bottom are the figures for the varying areas. The chart with the adult figure is used for ages 7½ years and up and the one with the child's figure for younger children. The two charts (Figs. 1 and 2) are printed on both sides of one piece of paper. In any one case only the side suitable for the patient's age is used.

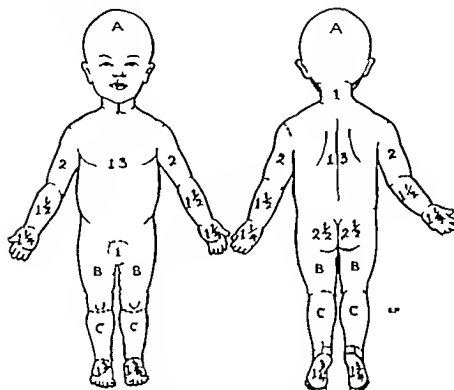
CHANGES ASSOCIATED WITH ABNORMAL BUILD

From the earliest studies on surface area it has been recognized that differences in body build result in differences in the relative area of different parts of the body. The surprising fact is that except for the changes during growth these differences in proportion are relatively small unless the differences in build are very gross. For instance Woerner measured a woman before pregnancy and at term. Her height was 5 feet 1 inch and her weight increased from 130 to 135 pounds. Her total surface area increased 4 per cent, with all of this gain limited to the trunk. The result was an increase in trunk proportions of only 3 per

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Name _____ Age _____ Number _____

Born Record. Age-Birth-7½ Date of Observation _____



RELATIVE PERCENTAGES OF AREAS AFFECTED BY GROWTH

Area	Age	5	1	3
A $\frac{1}{2}$ of Head	5"	8	8	8
B $\frac{1}{2}$ of One Thigh	5"	8	8	8
C $\frac{1}{2}$ of One Leg	5"	8	8	8

BURN BY AREAS

Probably Inf. Burn	Head	Neck	Body	Arm	Forearm	Hand
	Chest	Buttock	Thigh	Leg	Foot	
Total Burn	Head	Neck	Body	Arm	Forearm	Hand
	Chest	Buttock	Thigh	Leg	Foot	
Sum of All Areas	Probably Inf.			Total Burn		

Fig

Over for Older Persons

cent (from 35 to 38 per cent) and a decrease of approximately 1 per cent each in the proportions of the upper and lower extremities and of less than $\frac{1}{2}$ per cent in the proportions of the head and neck.

DuBois and DuBois measured a woman with great obesity. She was 4 feet 11 inches tall and weighed 203 pounds. Compared to

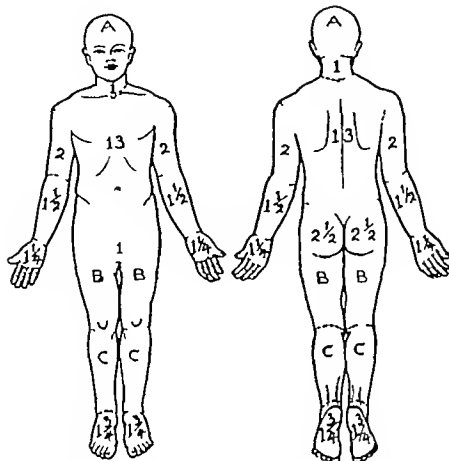
normal individuals measured by the same methods her trunk made up 42 per cent of her total area instead of 36 per cent. The arms were 12 instead of 14 per cent and the hands, legs, feet and head each approximately 1 per cent below normal. The thighs remained normal. As different obese individuals differ in the distribution of their excess fat other over

BOSTON CITY HOSPITAL

Name

Age

Number

Burn Record. Age $7\frac{1}{2}$ t Adult. Date of Observation

RELATIVE PERCENTAGES OF AREAS AFFECTED BY GROWTH

Area	Age	10	15	Adult
A = $\frac{1}{10}$ of Head	5 th	—	4%	8%
B = $\frac{1}{10}$ of One Thigh	—	4%	4%	4%
C = $\frac{1}{10}$ of One Leg	—	8	5%	8%

% BURN BY AREAS

Probably Not Burn	Head	Neck	Body	Up Arm	Forearm	Hand	—
Total Burn	Head	Neck	Body	Up Arm	Forearm	Hand	—
Probably Not Burn	Head	Neck	Body	Up Arm	Forearm	Hand	—
Total Burn	Head	Neck	Body	Up Arm	Forearm	Hand	—

Fig. 2.

Over for Young Children

weight patients would not necessarily show the same changes in proportion.

It is of interest that emaciation hardly changes the proportions at all. An example of this is case Gerald S. in Sawyer Stone and DuBois (8).

The condition that causes the greatest alteration in proportions is amputation. Sawyer

Stone and DuBois (8) measured and calculated 2 such patients that had bilateral thigh amputations. Each of these amputations left the patients with only about one half the original thigh skin and of course none for the legs and feet. The proportions in these patients were 51 per cent for the trunk, 26 per cent for the upper extremities, 9 per cent for

the head and 15 per cent for the remaining short atrophied thighs.

Even a single amputation at the knee makes more difference to the proportions than the case of pregnancy described. As the surface area of one leg and foot is about 10 per cent of the total, their removal, without any change in the size and shape of other parts would make the following alterations, as calculated from the data presented as standard proportions for an adult. Head from 7 to 7.8 per cent, neck from 2 to 2.2 per cent anterior and posterior trunk from 13 per cent each to 14.4 per cent each, buttocks from 5 to 5.6 per cent, genitalia from 1 to 1.1 per cent, upper arms from 8 to 8.9 per cent, forearms from 6 to 6.7 per cent, hands from 5 to 5.6 per cent, thighs from 19 to 21.1 per cent, remaining leg from 7 to 7.8 per cent and remaining foot from 3.5 to 3.9 per cent.

In the care of burns certainly less than 3/5 of 1 per cent of all cases admitted have such irregular body form that these considerations are of importance in estimating the surface area of the individual. If it is important to study such a case carefully his parts should be estimated by using DuBois and DuBois measurements (4) or the very slightly modified measurements of Sawyer Stone and Du Bois (8).

SUMMARY AND CONCLUSIONS

1 In studies of burns an easy accurate method of visual estimation of the percentage of surface area is important. Certain systematic errors of magnitude can occur when Berkow's table for adults is applied to children.

2 A new table and diagrams have been constructed that avoid these and other systematic errors.

3 It is estimated that this table and these diagrams should be applicable without serious error to at least 99.5 per cent of all cases of burns.

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THE VALUE OF SYMPATHECTOMY IN THE TRIATOMINI OF BUERGER'S DISEASE

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BUERGER'S disease is a chronic recurrent segmental thrombosis of peripheral and visceral blood vessels. It is preceded by a typical migrating phlebitis in 30 to 40 per cent of the cases. The lesions are frequently in the digital arteries or even more terminal segments but occlusion of major arterial pathways is often seen. It is necessary to exclude all well known causes of sudden or gradual vascular occlusions such as arterial embolism spontaneous closure of aneurysmal sacs senile atheromatosis and typhus typhoid fever malaria scarlet fever and the rheumatic infections which produce vascular reactions similar if not indistinguishable from Buerger's disease. Transitions to periarteritis nodosa are not uncommon.

In our present state of knowledge it is not even possible to say whether the endothelial reaction leading to thrombosis is on an infectious a toxic or an allergic basis or whether it is primarily due to changes in the blood which result in vasospasm and endothelial proliferation. One thing is certain sympathectomy does not modify the course of this disease it is undertaken only for the purpose of improving circulation in limbs in which blood vessels are occluded obviously then the patient who is a candidate for a sympathectomy must demonstrate the presence of an adequate collateral vascular bed and must show that he is in a quiescent stage of the disease to a state of remission or should the disease show too much visceral extension

PREOPERATIVE STUDIES

When a patient is admitted to the hospital for study a simple routine is followed to determine his operability. After a moderate dose of barbiturate the regional sympathetics

are blocked with procaine. On the upper extremity a cervical sympathetic block should result in a Horner's syndrome on the lower extremity the loss of sweating accurately determines the presence and level of sympathetic paralysis. The sympathetic block may be apparent in a few minutes or slowly develop within the next half hour. While measurements of skin temperature are desirable and can be easily carried out with a small skin thermometer with some little experience the observer can tell by palpation whether or not the extremity has warmed up sufficiently. As long as sweating is present in the areas under observation the sympathetic paralysis is incomplete and may have to be repeated. Special attention must be paid to the temperature of each individual finger or toe (Fig. 1) these digits may remain as cold as they were prior to the injection or their temperature may even drop in spite of a good rise of temperature in the more proximal parts. This paradoxical drop of skin temperature is very significant it means that not only will this digit not benefit from sympathectomy but a rapidly developing gangrene may occur following the operation. With increasing experience it has become obvious that such toes should be amputated immediately following sympathectomy. This combined operation will be discussed later in more detail. If the entire foot or hand remains cold after a successful block it means that the vascular capacity is very small that the occlusion is in the terminal arterial bed and that sympathectomy will not benefit the foot but it might still allow the performance of a Syme amputation. Claudication may or may not improve after sympathetic block. In some patients suffering from angiospastic claudication walking ability improved considerably (6). Thus in the case of C. W. (Fig. 1) the patient could walk 150 steps before and 650 steps after para-

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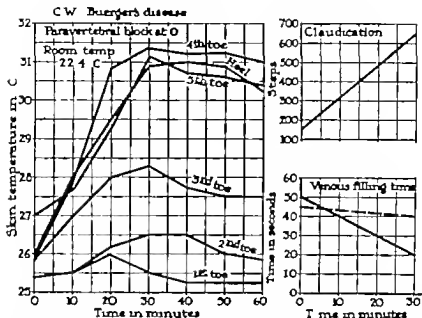


Fig. 1. The results of paravertebral sympathetic block in a patient suffering from Buerger's disease. Graph on left shows the rise in skin temperature of the 4th and 5th toes to the normal vasodilatation level (3°C). The heel warms up equally well. The 3d toe warmed up from 26 to 27.5°C . The 1st and 2d toes did not warm up at all. Such a patient needs an amputation of his 1st and 2d toes, the 3d toe will remain cold after sympathectomy but may improve with time. This same patient could walk 60 steps after sympathetic block without getting pain in the calf, against 30 steps before the block. This indicates that angiospasm is a factor in his claudication. The venous filling time (venous filling on the dorsum of the foot after 60 millimeters of mercury pressure was inflated into blood pressure cuff on the thigh) dropped from 50 to 30 seconds on the injected side; the change on the opposite side from 45 to 40 seconds is within the limits of error. Lumbar sympathectomy with amputation of the first two toes resulted in an excellent anatomic and functional recovery.

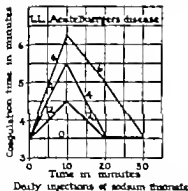


Fig. 2. Improving heparin tolerance of patient (L.L. Buerger's disease) after daily injections of 0.6 grams of sodium tetrathionate. Numbers indicate the days of medication with the drug. Note that on 0 day prior to the injections, the patient's coagulation time could not be raised with milligrams of heparin. With daily injections the response to heparin improves. On the 6th day the patient shows an excellent response. His clotting tendency has been corrected. He is ready for operation.

vertebral block. When such a finding is elicited the patient may be assured of an increased walking ability after sympathectomy.

Venous filling time is an excellent method of estimating the decreased rate of flow in an extremity has been slightly modified. The extremity is elevated until the dorsal veins collapse. With a blood pressure cuff around the thigh or upper arm, a pressure of 60 millimeters of mercury is produced and the limb placed in the horizontal position in a warm room. When the dorsal veins become prominent or show slight pulsation the veins are considered being filled. From the normal of 5 to 10 seconds, some extremities may show a filling time as slow as 120 to 180 seconds. In the case of C.W. the venous filling time shortened from 50 to 30 seconds indicating a good response to sympathetic block.

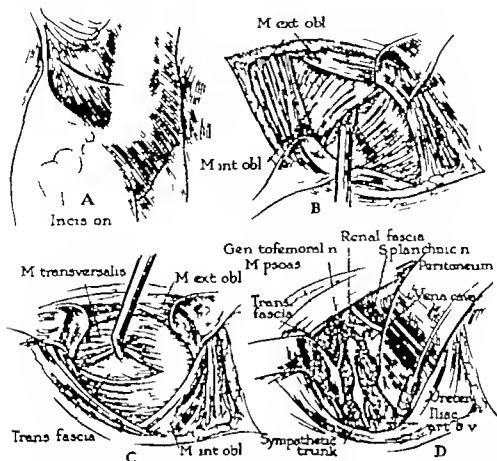


Fig. 3. Lumbar sympathectomy performed with an extraperitoneal anterolateral muscle-splitting approach. A. The incision starts in the midaxillary line, below the 12th rib and extends to the lateral border of the rectus muscle at the level of the umbilicus. B. The external oblique muscle is separated along the course of its fibers; the internal oblique muscle is in the process of separation. In very muscular individuals it may be necessary to cut this muscle parallel to the first layer of muscle. C. Both external and internal oblique muscles are retracted; the transversalis muscle is separated and the transversalis fascia becomes visible. D. The transversalis fascia is widely dissected off the psoas muscle and the sympathetic chain is exposed between the medial edge of the psoas and the vena cava. Dissection may be hampered by lumbar veins traversing the field or by a chain of enlarged lymph glands. Note the genitofemoral nerve which should be carefully protected from vigorous retraction since this may result in annoying paresthesias. The chain is removed from the level of the sacral promontory to the crus of the diaphragm. Closure is made in layers with cotton. The lighted retractors were abandoned several years ago for a head-lamp. Approach of Flothow.

After the capacity of the peripheral vascular bed to dilate when vasomotor tone is removed has been determined the next question is that of the activity of the process. Our group has availed itself of a simple test of the clotting mechanism: the heparin tolerance which is greatly depressed in patients with active Buerger's disease (2). The normal response of the individual to 10 milligrams of heparin is quite stable. Under certain conditions some of which have been studied and some of which are still under investigation the response to heparin is diminished. Buerger's

disease in its acute and subacute forms is one of the conditions characterized by a tendency to thrombosis as shown by the heparin tolerance. Since all major operations are followed by a temporary tendency to thrombosis it is important not to operate while patient is in a state of heparin resistance. Earlier before attention was paid to this phase of the problem the incidence of postoperative thrombosis after sympathectomy was high—4 per cent identical with that of a pelvic laparotomy.

Thesis and Freeland, on the basis of extensive chemical studies, advocated the use of

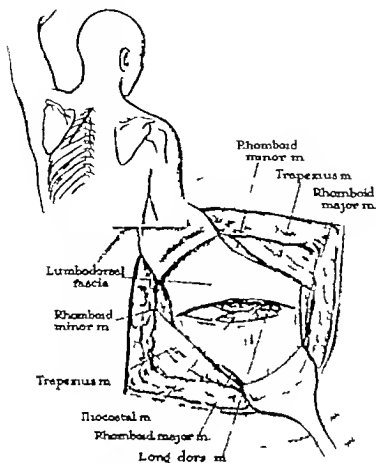


Fig. 42. Dorsal sympathectomy. Patient is in the prone position with an inflated horseshoe pillow under the head. His face rests on cerebellar rest. The incision starts slightly below and lateral to the spinous process of the 7th cervical (prominent) vertebra. The incision runs parallel to the medial border of the abducted scapula. The first layer of muscle, namely the trapezius, is split in the direction of its fibers. The rhomboid muscles, major and minor, are retracted and the strong lumbodorsal fascia is split transversely. The long muscles of the back are separated to expose the 3d rib.

intravenous sulfur compounds for the correction of the oxygen unsaturation which they found to accompany exacerbations of the disease. In a recent study I found that these sulfur compounds, notably sodium tetrathionate, restore the heparin response of such patients to normal (3). While in previous years it has been our practice to "cool off" the active process by a series of small doses of typhoid vaccine with complete abstinence from tobacco, now one can safely proceed with the operation in about 1 week (Fig. 2).

The heparin tolerance is thus a useful gauge of the activity of the disease in cases of recurrence brought about by trauma or renewed smoking; it flattens again. It also permits a close watch for postoperative thrombosis for which preventive measures are available.

Since the disease is far more widespread than would be obvious from a clinical examination, eyegrounds are examined, an electrocardiogram is taken, and renal concentration is determined. Isolated phlebitis or periphlebitis in retinal veins has thus been

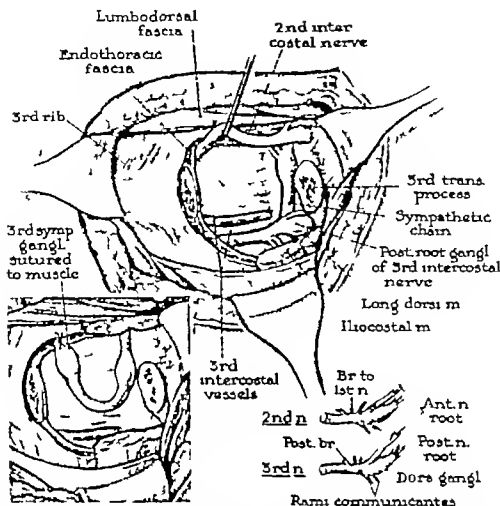


Fig. 4b The 3d rib has been resected paravertebrally for a length of 6 centimeters. The transverse process has been removed with a double action bone forceps. The pleura with the endothoracic fascia has been peeled off the vertebral bodies. The 2d and 3d intercostal nerves are pulled out gently from the intervertebral foramina and sectioned proximal to the posterior root ganglion intradurally. A small segment of the nerve is excised. (See insert in lower right quadrant.) The sympathetic chain is cut below the 3d dorsal ganglion and sutured to muscle or to the distal stump of the second intercostal nerve. A Cushing clip is placed on the lower end of the sympathetic chain. The wound is closed in layers with cotton. Method of Smithwick.

recognized myocardial damage is not infrequent. A small group of our patients had hypertension with typical arteriolar lesions of Buerger's disease in the periphery and another group had cerebral symptoms (Table I).

The finding of such widespread involvement does not necessarily contraindicate sympathectomy for one especially crippled part of the body but it aggravates prognosis and may require prolonged preoperative management.

CONTRAINDICATIONS TO SYMPATHECTOMY

Early cases of thromboangiitis with migrating phlebitis with closure of a single digital

artery or with an acute phlegmon of a finger or toe simulating gout are not suitable for sympathectomy; their sedimentation rate is slow and the hematocrit is high. Moreover patients over 50 years of age whose disease is slowly hurrying out and who have a certain degree of arteriosclerosis are generally not suitable for sympathectomy; the vasomotor element is not striking. The operation is indicated when the disease seems quiescent when the hemoconcentration is corrected when the collateral blood supply is satisfactory and when the visceral involvement is not too widespread.

TABLE I—VISCERAL LESIONS IN THROMBO-ANGIITIS OBLITERANS

	No. present	Percentage of total
Number of patients studied	50	
Retinal lesions {vasoconstriction periphlebitis}	3	50
Cerebral vascular lesions	5	
Electrocardiogram, abnormal pattern	28	56
Duodenal ulcer	5	
Impaired renal function	8	6
Pulmonary fibrosis		4
Occlusion of spermatic artery		

1. It is not implied that these lesions are necessarily due to thrombo-angiitis.

THE SURGICAL PROCEDURES

Lumbar sympathectomies have been done alternately under intratracheal ether or high spinal anesthesia. Since the approach used is an extraperitoneal anterolateral muscle splitting incision (5) complete muscular relaxation is very important. Bleeding from lumbar vessels is controlled by Cushing clips. A retroperitoneal lymphangitis and lymphadenitis may greatly interfere with dissection. These may be encountered even when there is no infected ulceration in the periphery. Biopsy or culture of these lymph glands has not yielded any specific information. The ganglionated trunk should be removed from the sacral promontory to the diaphragm but at least between the top of the 1d to the bottom of the 3d lumbar vertebra. The number and size of the ganglia vary a great deal and duplicate chains are sometimes encountered (Fig. 3). Patients usually get up the 5th and go home the 10th postoperative day.

The dorsal sympathectomy for the arm is done under intratracheal ether anesthesia. The 3d rib is resected paravertebrally the 2d and 3d intercostal nerves with the corresponding anterior and posterior roots are removed intradurally and the chain is sectioned below the 3d ganglion. The distal end is clipped with a metal clip the proximal end is imbedded into muscle. We do not wrap the chain into a silk cylinder but otherwise follow the method described by Smithwick (Fig. 4). The patient is allowed to get up on the 3d day and may be home on the 8th day.

In a number of cases amputations have been performed during the time of sympathectomy especially on the lower extremities. As stated

before if the paravertebral block results in a failure to warm a certain part or especially if a paradox drop of temperature is observed the corresponding digits are removed. To obtain primary union it is necessary to obtain positive histamine flares at the level of amputation to use absolutely no tension on the sutures, and to suture nothing but skin. When all five toes need to be amputated a Gigli saw is used. With the protection of a sympathectomy a Syme amputation has been recently used in patients who without the sympathectomy would have had to have a lower leg amputation. The results of this combined operation of sympathectomy and amputation will be discussed in more detail.

Lately the skin incision has been placed so as to run parallel with the fibers of the external oblique muscle. A detailed description of this excellent technique which avoids under cutting of the skin and subcutaneous tissue and provides excellent exposure is given by Pearl in a recent contribution.¹

POSTOPERATIVE MANAGEMENT

Patients following lumbar sympathectomy receive prostigmine every 4 hours in 10 doses. This not only controls intestinal and bladder atony but has a beneficial effect on the clotting tendency of the postoperative status (4). In addition sodium tetrathionate is used (3) ampuls the first day in the intravenous fluids, and 1 ampul daily until the patient is mobilized.² This, too, is useful in counteracting the heparin resistance which such patients exhibit after operations. There has been no thrombosis or embolism in this small series, but of course this is statistically meaningless. However even an established migrating phlebitis of Buerger's disease responds very quickly to this treatment.

RESULTS OF SURGICAL PROCEDURES

To evaluate the results, a grouping of these patients into (1) those who have had only sympathectomies, (2) those who had sympathectomies combined with minor amputations and (3) those who had sympathectomies combined or followed by major amputations

¹Frank, F. L. *Surg. Gyn. Obst.* 1937, 6, 127.
²Sodium tetrathionate should never be used in combination with sodium contrast media.

seemed practical. Table II shows the results obtained. Obviously the first group is the least advanced one the two part time workers had not secured inside jobs and probably could be placed to do full time work elsewhere the two invalids were of the lowest economic and intellectual level and their re-education seemed impossible. In the second group the 3 patients who could work only part time were middle aged laborers streetcar conductors or railroad workers. The invalids had cerebral involvement. In the last group 2 patients could not be fitted with artificial legs and 1 patient had a pension which allowed him to live without having to work.

POSTOPERATIVE COURSE

Horton has written a very interesting article in 1938 on the outlook in thromboangitis obliterans and thought that the most important factors which determine whether a person who has thromboangitis obliterans will walk on two feet throughout life are early diagnosis and education of the patient concerning the nature of his disease and the care of the extremities. One thing that our group has learned is the importance of re-educating and reallocating these patients to jobs which will expose them less to the hazards of trauma exposure to cold or excessive use of the feet. All patients suffering from Buerger's disease should be regarded as handicapped. If they are office workers their jobs should be sedentary, if they are laborers their jobs ought to be inside. A streetcar conductor with thromboangitis obliterans is just as unfit for his job as if he were a parachute trooper or an aviator. Widespread use of agencies to reallocate such people will result in continued improvement.

Table III shows the occupations of this group of patients. Most surgeons are emphatic about abstinence from tobacco and about the care of the feet. How many of us are emphatic about a change of occupation? It is not enough to suggest it, but one should also aid the patient by agencies now available for the purpose. This is surely as important as the printed directions regarding the care of the feet but more difficult to accomplish.

Our patients are instructed to appear every 3 months for a year and then once a year for a

TABLE II — RESULTS OF SURGICAL TREATMENT IN BUERGER'S DISEASE

Group	No. cases	No. operations	Full time work	Part time work	Invalid
	4	56	30		
		63	5	3	3
3	5	7			
Total	30	66	37	7	6

Group 1 had only sympathectomies.

Group 2 had sympathectomies combined with minor amputations.

Group 3 had sympathectomies combined with major amputations.

re-examination. They are given printed instructions regarding the dangers to avoid. They are advised to take two series of 12 daily injections of sodium tetrathionate during the first year. They are taught the use of intermittent venous hyperemia on the sympathectomized extremity which method is notoriously ineffective in this disease unless the vasomotor control is interrupted. While these measures are important they are of not very much use without sympathectomy. Fourteen patients with unilateral sympathetic denervation are vociferous witnesses of the progress that the extremity operated upon makes compared with the other limbs. These patients to my mind are the most convincing proof of the value of sympathectomy in the presence of Buerger's disease.

SUMMARY

Sympathectomy deprives the extremity of its vasoconstrictor tone. It does not influence the course of Buerger's disease. However when this disease is in an inactive phase and when adequate preoperative tests reveal the presence of sufficient collateral vascular supply sympathectomy will aid an extremity considerably whose vessels have been crippled by recurrent attacks of segmental thrombosis. In this series of 50 patients 136 sympathectomies have been done about one half of these patients have also had minor amputations combined with sympathectomy. Of the 50 patients 37 have been rehabilitated to full time work 7 are doing part time work and only 6 are invalids. In addition to foot hygiene and complete abstinence from tobacco a change of occupation is important for those whose feet are continuously subjected to an exposure to cold or trauma.

TABLE III—OCCUPATION OF PATIENTS

Office work	3
Physician	5
Lawyer	1
Housewife	3
Laborer	8
Outside work (motorman, et.)	5
Travelling man	7
Farmer	5
Total	50

ILLUSTRATIVE CASE HISTORIES

CASE 1. John S. 32 year old streetcar conductor complained of claudication after one block. He had had pain in lower leg and foot since hitting the dorsum of his left foot with tennis racket years ago. Erythematous patches occurred during the cold months. Ring finger of right hand became blanched 3 times. Gastric ulcer was food in January 1933. He had always been heavy smoker. On entrance to hospital left foot was colder than right. Erythematous induration was present on left tibial margin. Heparin curve showed increased tendency to clotting. Sympathetic block 2nd, 3rd, and 4th lumbar ganglia gave moderate rise in temperature. The big toe remained cold. Claudication 175 steps before block walked 30 minutes after block without pain. Electrocardiogram revealed right axis deviation.

Operation on June 7, 1933 consisted of a left lumbar sympathectomy. Big toe became warm under ether anesthesia and was amputated. Large lymph glands were encountered retroperitoneally. On January 7 months after operation this patient reported that he worked 8 hours a day as bus driver. He could play 3 holes of golf. The big toe was sometimes numb. He stopped smoking and took two courses of sodium tetrathionate.

This patient a 32 year old male with a pronounced angiospastic claudication derived great benefit from a lumbar sympathectomy. His big toe seemed to have most of the organic damage but the disease seems to have been arrested at this stage.

CASE 2. J. J. M. a 39 year old pharmacist entered St. Luke's Hospital on November 8, 1930 complaining of persistent severe pain at rest, inability to walk, and inability to sleep, with symptoms gradually increasing for the last 5 years. He was frostbitten at the age of 8 and had always seemed sensitive to cold. He had smoked to 3 packages of cigarettes daily for 30 years. His right 4th toe had ulcerated 4 weeks ago. He had been previously treated for Raynaud's disease. On entrance the right lower extremity was cold, the toes cyanotic, the 4th toe ulcerated. There was extensive dental infection. The electrocardiogram P was inverted, T low. Fifteen minutes after the intravenous injection of phenolsulfonphthalein 50 per cent was excreted in the urine showing a delay in

excretion. The esophagus showed arteriolar constriction and tortuosity. A stellate block had a definite dilator effect indicating vasospasticity. Operation on November 16, 1930, consisted of a right lumbar sympathectomy. Considerable lymphadenopathy was noted. A follow-up in December 1933 revealed that he could walk from 3 to 4 blocks, that he was working 8 hours a day in a defense plant. The ulcer had completely healed.

This 39 year old pharmacist has been followed for 3½ years after sympathectomy. The disease seems to be arrested. He is able to perform full time work.

CASE 3. E. F. S. 41 years old, unemployed, entered St. Luke's Hospital on April 19, 1930, complaining of pain, numbness, cramping on walking for the past 6 years. He had not worked for 3 years. On entrance both lower extremities were pale, cold and pulseless below the knees. There was a massive necrosis of the entire left big toe which was present for over a year. He had been previously treated for diabetes and for syphilis. Maggots were applied to the toe. The electrocardiogram revealed slightly elevated S-T segment in lead II. Renal concentration was within normal limits. The veins were slightly darker than usual in the retina.

On April 20, 1930, a right lumbar sympathectomy on May 5, 1930, a left lumbar sympathectomy on May 8, 1930, amputation of the left big toe were performed. A follow-up inquiry in December 1933 revealed that he could walk 3 miles without pain, had an occasional twinge; the left toes which passed immediately and that he was at full time work in a defense plant.

This 41 year old male unable to work for 3 years, had been fully rehabilitated by bilateral lumbar sympathectomy and amputation of one toe. Period of follow up was 4½ years.

CASE 4. Nick F. 53 year old foreman, entered St. Luke's Hospital complaining of pain and increasing inability to walk very far for the past 3 years. He first noticed sensitivity to cold and cramping on walking, first in right and then in left leg 20 years ago. In December 1911 a paronychia developed in left big toe when the toenail was removed the toe became gangrenous. He smoked a package of cigarettes a day for many years.

On entrance he had claudication after 5 feet. There were diminished femoral, absent popliteal and pedal pulses on the left. The big toe was gangrenous. The right foot was equally pulseless but warm and painless. Blood pressure was 50/90. Ratio of velocity arteries in the retina was 1/2. The electrocardiogram showed W-shaped QRS complex in lead III. X-ray examination of the popliteal fossa showed some calcification.

Operation was done on January 9, 1942. A left lumbar sympathectomy was done with removal of the chain between 2d and 4th lumbar segments. The toe was removed 5 days later since his blood pressure fell to 60 millimeters of mercury probably because of his posture on the table. A plantar abscess had to be drained before the incision on the foot completely healed. Re-examination 9 months and 12 months after sympathectomy revealed an ability to walk 4 to 5 blocks a day, both feet were painless. He works on his feet 10 to 12 hours a day. Oscillometer revealed a $\frac{1}{4}$ centimeter oscillation at 100 millimeters of mercury at both ankles. These were absent prior to operation.

This 53 year old male with signs of beginning arteriosclerosis superimposed on an old Buerger's disease increased his walking ability from 50 feet to 4 blocks and could do a full day's work after a combination of sympathectomy and minor amputation. The differential diagnosis between presenile atherosclerosis and Buerger's disease is not possible in this case. Both may have been present.

CASE 5. E. M. R., a 35 year old automobile sales man, complained of intermittent claudication for 2 years and a left infected ingrown toenail for 2 years. He had been treated by a chiropodist until 1941 then by a physician who incised his foot. He visited a university clinic, where he received instructions for the care of his feet. On entrance to St. Luke's Hospital there was bilateral absence of pedal pulses but both popliteals were present. His heparin curve was 3 5 3 3 minutes, coagulation times being determined every 10 minutes. After a course of sodium tetrathionate the coagulation times were 4, 7 $\frac{1}{4}$, 6 4, 4. Sympathetic block to 2d lumbar segment resulted in marked vasodilatation and dryness of the

right foot and toes. The left toes remained cold. Electrocardiogram revealed a low QRS in leads I, II and III.

On January 23, 1943 left lumbar sympathectomy was performed. There was a large chain of lymph glands. On February 8, 1943 a right lumbar sympathectomy was performed and again a great deal of lymphadenitis was encountered. He went to work in a railroad yard exposing his feet to much trauma and cold. He never stopped smoking even while in the hospital.

A follow up in November, 1943, 6 months after a bilateral sympathectomy revealed that his left leg had been amputated at Cook County Hospital.

This 35 year old male had a severe terminal type of Buerger's disease. Bilateral lumbar sympathectomy was done but this failed to prevent the loss of one leg. Possible causes of this failure: (1) inability to stop smoking, (2) unsuitable outside manual labor in a man used to indoor desk work, (3) failure to remove toes at the time of sympathectomy which failed to warm on sympathetic block.

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HYPOPROTEINEMIA IN THORACIC SURGERY

A Clinical Study

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RATHER extensive studies have been made on the effect of hypoproteinemia in surgical diseases. It has been found that certain conditions particularly long standing intestinal obstruction are prone to produce a marked lowering of the plasma proteins. The effect of this hypoproteinemia on wound healing and disruption postoperative infections and rate of recovery has been the subject of many observations (3, 3, 5, 6). Most of the work to date has concerned major abdominal surgery. The surgical treatment of diseases of the chest may also be complicated by hypoproteinemia largely due to the chronicity of many lung diseases and the relatively severe blood loss associated with major thoracic surgery.

Over a 12 month period the effect of the more common chest operations on plasma proteins has been investigated. The studies were conducted in the following manner. Preoperative plasma protein and hematocrit determinations were made on all patients. During the operations and in the postoperative period rather large whole blood and plasma transfusions were given to replace blood loss. No operations were begun without a cannula in place and blood started or available. Infusion was usually discontinued in explorations for inoperable lesions in the case of resections, blood was added to roughly compensate the loss. At 2 day intervals following operations the plasma proteins and hematocrit determinations were repeated. The study was continued for 10 days, or until the readings returned to the preoperative level. All protein determinations were made in the hospital laboratory by the micro Kjeldahl method (4). Included in the series are 33 major operations on 29 patients classified as follows:

Lobectomy		
a. Left lower	6	4
b. Left lower and lingula		
c. Right lower		
d. Right middle		
Right middle and lower	3	
Pneumonectomy		5
1. Expiratory thoracotomy		7
4. Miscellaneous		6
First stage lobectomy		
b. Esophageal resection		
Partial pericardectomy		
d. Extensive thoracoplasty		

One patient succumbed 15 days after operation due to anuria and uremia induced by sulfathiazole. The remainder recovered from the operation satisfactorily.

RESULTS

Pertinent data on the individual patients are presented in Table I. Despite the fact that chronic suppurative lesions and carcinoma were the most common diseases preoperative hypoproteinemia was rare. Only 2 patients had basal readings below 6.00 grams per cent. Following operation a rather marked fall in the plasma proteins occurred in every patient but one. In the case of lobectomy this fall averaged 1.11 grams per cent and varied from 0.44 to 2.91 grams per cent. The greatest fall occurred in 4.4 days and the preoperative level was regained in 9.0 days. The drop in plasma proteins was accompanied by a hematocrit fall of 5.8. The lowest hematocrit reading occurred in 4.3 days and had returned to the preoperative level in 9.5 days. The fall in hematocrit was not constant. 5 cases of lobectomy maintained the preoperative hematocrit level the greatest drop being 15 points. At the time of lobectomy the average transfusion was 942.8 cubic centimeters of whole blood in the postoperative period an additional 782.1 cubic centimeters were given.

The average plasma protein fall in 5 cases of pneumonectomy was 0.95 gram per cent, the range being from 0 to 1.54. The greatest drop

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TABLE I

Initial	Diagnosis	Operation	Infection	Replacement in	Plasma proteins					Hematocrit			
					Pre-op	Fall	P.O.	Day fall	Day return	Fall	Day fall	Day return	Pt. #
Lobectomy													
M B	Branchectasis	Left lower lobectomy	+	none at operation		60			—	—	—	—	yes
M S	Branchectasis	Left lower lobectomy	—	yes at operation yes after	6.94	5				5			yes
J M	Branchectasis bilateral	Left lower lobectomy	—	yes at operation	6.1		58			—	—		600
J C	Congenital cystic disease	Left lower lobectomy		yes at operation yes after	6.53	90	57			5		Not back	7
A R	Diffuse suppurative pneumonia, parametritis	Left lower lobectomy	—	yes operation yes after	66	81	58	14	5			Not back	50
S R F	Branchectasis	Left lower lobectomy	+	yes at operation yes after	60	45	45	5		15		10	16
M S	Tuberculous bronchiectasis	Right lower lobectomy		yes operation yes after	36	5		6		6			8
S L F	Congenital cystic disease	Left lower lobectomy part of left upper	—	yes blood at operation yes plasma yes blood after	52	91						5	
S E	Bilateral bronchiectasis	Left lower lobectomy left lower lobectomy	—	none at operation	6.5	76	6.7			—	—		930
A S	Bilateral bronchiectasis	Right middle and lower lobectomy	—	yes operation yes after		45		Did not return		—	—		990
D G	Bilateral bronchiectasis	Right middle and lower lobectomy		6-8 before operation none at operation yes after		60	65			—	—		yes
R T	Emphysema	Right middle and lower lobectomy		yes at operation yes after	15	44							430
J M F	Congenital cystic disease	Right middle lobectomy		yes at operation		70	6			6			50
E S	Diffuse suppurative pneumonia	Right middle lobectomy		none at operation	6.81	66		Did not return				at back	430
Average 14			2+	6.15 E at operation none after	6.8	81		6	5.8	5	5	5	673.3
Pneumectomy													
M R	Carcinoma lung	Left total pneumectomy	+	yes at operation yes after	44	14	5.82			36			7
L R	Carcinoma lung	Right total pneumectomy	—	yes at operation yes after	5					6			7
J K	Carcinoma lung	Right total pneumectomy	—	none at operation yes after	44	30	6.1						7
G S	Carcinoma lung	Right total pneumectomy	—	yes operation	6	66	66					6	7
R R	Hemangioma	Left total pneumectomy	—	yes operation yes after		15				30			7
Average			—	none at operation yes after		66	7						7

adequate as evidenced by the postoperative fall in hematocrit. The hematocrit determination was employed because it was found to be more sensitive and accurate than the usual hemoglobin or red cell count. Eight patients in the entire group did not have a postopera-

TABLE I—Continued

Initial	Diagnosis	Operation	Infection	Replacement in c.	Plasma proteins					Hematocrit			
					Pre op	Fall	P O	Day fall	Day return	Fall	Day fall	Day return	Pt. d. loss
Exploratory Thoracotomy													
C.S.	Carcinoma lung	Exploratory thoracotomy	—	000 before operation 500 1 operation	7.33	5	6.00	6	9	—	—		
A.K.	Tuberculosis?	Exploratory thoracotomy	—	500 1 operation	5.93	80	3		4	5	5	Not back	475
J.E.B.	Carcinoma esophagus	Exploratory thoracotomy	—	500 1 operation	6.8	00	3.8		3	3.5	3	Not back	350
F.R.	Carcinoma lung	Exploratory thoracotomy	—	500 at operation	3.70	70	5.3		3	3	3	Not back	
M.N.	Carcinoma lung	Exploratory thoracotomy	—	000 at operation	7.60	34	8.35	7	Not back	3	3	7	0
E.S.	Mediastinal cyst	Excision of	—	500 1 operation	6.7		3.70		Not back	6	4	6	50
C.H.	Carcinoma esophagus	Thoracotomy	—	000 1 operation	6.3	40	6		Not back	4	6	Not back	300
Average 7				6.1 1 operation after	6.60	77	3.84	3.3	6.7+	4.8	6	+	67.8
Miscellaneous													
R.T.	Bronchial adenoma	First stage lobectomy	—	500 1 operation 500 after	6.83		5.66	6	3	3		8	
L.B.	Carcinoma esophagus	Esophagectomy anastomosis	+	500 1 operation 500 after	6.44	93	5.46	6	3	6	4	3	400
J.V.	Carcinoma esophagus	Torek	—	50 1 operation	6.3	13	5.95		6		3	Not back	00
F.V.W.	Constrict pericarditis	Partial pericardectomy	—	500 at operation	6.94	8	5		3	8	8	Not back	3700
O.S.	Post pneumonectomy empyema	Thoracoplasty	+	500 1 operation 500 after	8.4		5.40		0	6	4	7	Open
L.R.	Post pneumonectomy empyema	Thoracoplasty	+	500 1 operation 500 after	8.91	78	6.8		6		—	—	Open

tive hematocrit drop. These patients would be expected to show a less severe fall in plasma proteins. Unfortunately 4 of the 8 patients developed postoperative infections which complicated the picture and on the average these patients had as marked a protein fall as the entire series. It is probably true however that the fall in protein would be minimal if the hematocrit could be maintained at a constant level.

Following operation there is a short period of negative nitrogen balance due to restriction of diet. Usually this is not as prolonged as in major abdominal surgery. After pneumonectomy the remaining pleural space is obliterated largely by serum from the blood stream. Following lobectomy a considerable amount of bloody serum is aspirated from the pleural

cavity with a needle or continuous suction. We have measured this loss in 12 consecutive lobectomies and find that it averages 673.3 cubic centimeters. Further loss of serum occurs if the wound becomes infected. The postoperative loss of serum and blood presents the same problem as operative hemorrhage with the exception that the loss is over a period of days instead of hours and the fluid contains fewer red cells. This may offer an indication for the use of blood substitutes and plasma which would also tend to neutralize the effect of the negative nitrogen balance.

Some consideration should be given to the optimal time for replacement therapy. In this group of patients preoperative transfusions were usually not given unless an anemia of less than 4.0 million red blood cells was present.

If operative blood loss is unusually severe or if the infusion apparatus functions poorly the replacement may fall far short of the loss. It seems advisable to anticipate such incidents and employ preoperative transfusions to a greater extent than is usually practiced particularly if the plasma proteins are low before operation. This would provide the patients with a margin of safety should a minor accident occur in the operating room with the infusion set-up or the supply of blood. Should a marked fall in the plasma protein level occur after operation further transfusions should be given promptly as will be shown.

If a postoperative infection occurs there is further loss of protein and electrolytes. There can be little doubt that a fall in plasma protein occurs with severe infection. Infection occurred following 9 of the 32 operations in this series. The protein fall in the infected patients averaged 1.19 grams per cent as opposed to a fall of 0.93 gram per cent for the noninfected group and 0.99 gram per cent fall for the entire series. In view of the susceptibility of debilitated patients to infection the hypoproteinemia may be the cause rather than the result of some postoperative infections.

Some indication of the individual effect of these various factors was determined in experimental work recently reported from this laboratory (1). With dogs as the experimental animal it was found that ether anesthesia alone caused an average plasma protein fall of about 0.50 gram per cent. Exploratory thoracotomy resulted in a fall of 0.85 gram per cent. Left lower lobectomy was accompanied by a protein drop of 1.5 grams per cent. Removal of the left lung caused the protein level to fall about 1.3 grams per cent. If infection occurred the drop was more marked and stayed at a low level longer than in noninfected animals. The use of whole blood intravenously and serum intravenously or intrapleurally partially prevented the plasma protein fall. The most striking feature of the study was the marked lowering of plasma proteins by postoperative infection.

A comparison of patients demonstrating the most marked protein fall against those who had a slight drop serves to emphasize the cause for postoperative hypoproteinemia. Using the

lobectomy group as an example we found that Cases 8, 2, and 1 had the greatest drop (2.91 gm.%, 1.82 gm.%, and 1.60 gm.% respectively). Cases 12, 3, and 7 had the least fall (0.44 gm.%, 0.46 gm.%, and 0.55 gm.% respectively). In the group of 3 patients demonstrating the severe fall operative blood loss was excessive in only one instance (Case 8). Postoperative fluid loss was slightly less than in the average case. One of the 3 patients became infected. However replacement therapy was not adequate. The average transfusion at the time of operation was 766 cubic centimeters with an additional 466 cubic centimeters during the postoperative period. (In Case 8 for simplicity a 300 cubic centimeter plasma transfusion [at the time of operation] is included with the figures for whole blood.) The hematocrit determinations show the same trend. Case 1 had no fall but Cases 2 and 8 had hematocrit drops of 13 and 15 respectively an indication that replacement was entirely inadequate.

In 2 of the patients with a slight protein drop blood loss at the time of operation was extreme (Cases 3 and 12). The postoperative loss of fluid into the pleural space was no greater than the average. No postoperative infections occurred. Considerably more blood was given than in the first group. Case 3 received 1500 cubic centimeters of blood at operation. Case 7 was given 700 cubic centimeters of blood at operation and 800 cubic centimeters after operation. Case 12 received 2700 cubic centimeters of whole blood during the operation and 2100 cubic centimeters during the first week following operation. The hematocrit readings reflect the extensive replacement the fall in Cases 3, 7, and 12 was 0.5 and 7 respectively. This comparison demonstrates the extreme importance of massive blood transfusions if replacement closely approximates the loss much less deviation from the preoperative values occurs.

The fall of plasma proteins following operation is largely of academic interest unless the value reaches a point sufficiently low to be of some danger to the patient. Obviously if the preoperative value was well over 7.00 grams per cent the loss of 1.00 gram per cent still leaves the plasma proteins in the normal range. It is necessary to consider whether an appre-

ciable number of patients drop into a dangerously low level which is usually considered to be in the neighborhood of 5.50 grams per cent. Of the 32 operations reported here 11 caused the plasma proteins to fall below 5.50 grams per cent. The lowest reading was 4.62 grams per cent (Case 8 in the lobectomy group). These 11 patients did not have a higher incidence of infection than the rest of the group but they were for the most part cases in which smaller amounts of blood were given. The fact that one third of the patients fell below 5.50 grams per cent following operation is a clear indication of the practical importance of this problem.

The prompt recovery that occurred in all but 1 patient in this group is partially due we believe to the liberal use of whole blood. If the transfusion given at operation did not prevent a fall in plasma proteins blood was given liberally after operation until the protein level was well above 5.50 grams per cent. The frequent use of the hematocrit determination is a rapid simple method by which the amount of infused blood can be controlled until a protein reading is available.

SUMMARY

1. A plasma protein fall of approximately 1.00 gram per cent occurred following major

thoracic operations. This drop was constant; it occurred in 31 of 32 operations reported in this series.

2. The fall usually occurred from 3 to 5 days following operation and was accompanied by a similar decrease in hematocrit, hemoglobin and to a lesser degree red blood cells.

3. The principal causes of the drop in plasma protein were (a) diminished protein reserve (b) operative blood loss (c) loss of blood and plasma into the wound and pleural space after operation (d) infection (e) inadequate replacement.

4. Massive transfusion of whole blood was the most satisfactory single therapeutic agent when the plasma proteins were lowered due to hemorrhage.

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MATERNAL OBSTETRICAL PARALYSIS

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THE study of those parts of a field of investigation in which different aspects of knowledge meet on common ground might be expected to be a particularly valuable one. In such zones of overlap the scrutiny of problems from different viewpoints may lead to their rapid solution. It is therefore surprising to find that these frontier territories have frequently been left relatively unexplored. Certain neurological complications of pregnancy and labor illustrate this point. Although the complications fall within the practice of the obstetrician, being neurological they are usually of but little interest to him. On the other hand the neurologist probably sees but a small proportion of these cases and has as a result tended to regard the conditions as rare complications of pregnancy and labor. A study of the well known textbooks of obstetrics and medicine reveals that, for the most part, the neurological disturbances to be considered either have been entirely overlooked or receive but the briefest mention. This neglect cannot be attributed to the rarity of their occurrence and indeed it appears likely that weakness of certain muscles of a lower limb after labor is a great deal more common than is generally realized. As a result of certain personal observations it is believed that further light can be shed upon this group of cases, and the purpose of this paper is therefore to attempt to lead to a better understanding of certain results of the physical trauma of childbearing.

THE MODERN TEACHING

Under the title of neuritis of pregnancy and the puerperium there are grouped together several conditions of differing etiology. In one group of cases the evidence of neurological disturbance is irregularly distributed throughout the body and may be severe and widespread. It has been suggested that toxæmia

vitamin deficiency and puerperal sepsis may be important etiological factors in these cases. This group is outside the scope of the present communication, however, and will not be further considered. In a second and larger group the neurological disturbance affects one or both lower limbs. It takes the form of a so-called peripheral neuritis and may arise in pregnancy or follow labor. This paper is concerned solely with the second group of cases that is neuritis involving the lower extremities. The development of the modern conception of the etiology of this condition will now be briefly considered. Arguments against this modern view will then be put forward. Finally evidence for an alternative explanation will be given.

In 1854 Fleetwood Churchill collected from the literature and his own experience a series of 34 cases of paralysis occurring during gestation and in childbed. Cases of several types are recorded and some of them appear to have been paralyzes of cerebral origin. Four cases of lower limb paralysis of the type now under consideration were included in his collection. One of these had been described by Beatty in 1836. The author makes it clear that such paralyzes were well recognized in his day. He quotes Campbell as attributing the condition to the long continued presence of the fetal head in the maternal pelvis (Fig. 1). Campbell considered that this was due to disproportion and believed that it resulted in injury to the sacral plexus. Churchill points out, however, that other authors had indicated that the paralysis might follow the easiest labors as well as the most difficult instrumental ones. He also states that Romberg recognized the condition but disagreed with the obstetricians' view that paralysis was due to pressure on the sacral plexus, suggesting instead that it resulted from an accumulation of fluid in the spinal canal. In 1893 Humermann stated that in these cases the muscular weakness almost always affected the muscles supplied by the external popliteal nerve. He

From The Surgical Professorial Unit, St. Bartholomew's Hospital. This paper formed part of a thesis approved for the M.S. degree of London University and was given at a meeting of the Society of British Neurological Surgeons in October 1943.

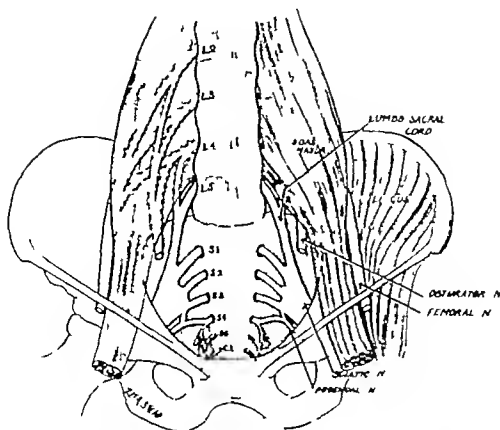


Fig. 1. Drawing showing the relationship of the femoral nerve, lumbosacral cord and sacral plexus to the body wall of the true pelvis.

suggested that this was because the lumbosacral cord was injured by the pressure of the fetal head. He considered that the exposed position of this nerve as it crossed the pelvic brim rendered it particularly liable to injury (Fig. 1).

In 1900 Thomas described 2 cases of lower limb paralysis after labor and supported the view of Hunermann. He further suggested that the term maternal obstetrical paralysis be used to describe these cases and distinguish them from the commoner infantile obstetrical paralysis. In 1933 Beattie reported 3 cases and pointed out that in 2 of these the presentation was such that pressure of the fetal head on the lumbosacral cord could not have been responsible for the neurological disturbance. As an alternative he suggested that the nerves might be injured during the application of the blades of the obstetrical forceps.

It has thus been widely accepted that these paralyses are due to injury of the lumbosacral cord or sacral plexus by the fetal head or the

obstetrical forceps. The only alternative explanation encountered in the literature is that of Lamberti (1924). This author objects to the view that maternal birth palsy is due to compression of the lumbosacral cord by the fetal head. He points out that the paralysis may occur on the opposite side to that through which the greatest diameter of the fetal head passes during labor and states that any mechanism which explains this rare postpartum paralysis should take into account the common antepartum sciatic pains. He suggests that during the latter part of pregnancy and in labor a rotation backward of the sacrum occurs to enlarge the pelvic inlet. This causes traction on the lumbosacral cords and as a result pain of sciatic distribution and less often paralysis appear. It is believed that this author's suggestion of a common causative lesion in sciatica and in paralysis occurring in pregnancy and the puerperium is an important one. Further it is believed that his view that both occurrences result from traction rather

18 months until in September 1941 her second child was born. The pregnancy had been normal and after a short and normal labor she was delivered of a child weighing 6 pounds. She got up a week after labor and immediately developed pain in the right buttock, posterior thigh and calf radiating on to the outer part of the dorsum of the foot. There was some backache and numbness and tingling were experienced in the painful areas. The pain rapidly became more severe and becoming completely incapacitated she again presented herself for treatment. On examination the signs were essentially as they had been at the time of the first examination with the addition of a marked scoliosis convex to the right in the lumbar region. She was observed for a period of 6 weeks during which no improvement was evident. At the end of this period exploration was carried out and a further large intervertebral disc protrusion removed from the lumbosacral disc. Again there was immediate relief of symptoms and the patient remains well.

Case 2 Mrs M W. aged 27 years came to hospital in October 1942 complaining of left sciatica. She gave a long history of backache and sciatica. Twelve years previously she had strained her back during a gymnasium class and developed severe lumbar pain which persisted for some days. Subsequently she had been liable to mild and infrequent attacks of backache. Six years before her admission she developed left sciatic pain after another back strain and this kept her in bed for some weeks. After this she slowly cleared up but there remained a tendency to pain in the limb during damp weather. Again 3 years before her admission she had an attack of sciatica followed by severe left sciatica. On this occasion she was troubled by pain for many months after a month's rest. It was relieved after 2 months by manipulation. It was relieved she became pregnant and was well until the latter part of the pregnancy apart from suffering from occasional cramps in her left leg. Two days before the birth of her child she noticed severe lumbago and left sciatica and she developed severe lumbago and left sciatica as it caused severe cramp in the left leg. Labor lasted 24 hours, no instruments were used, and she was delivered of a child weighing 7½ pounds. After delivery the patient was free from pain until she got up on the 9th day. Low back and left sciatic pain reappeared immediately and became very severe. The pain was of typical sciatic distribution and spread onto the lateral aspect of the ankle. It was aggravated by coughing, straining etc. and relieved by rest and attitudes of flexion. There was an associated numbness over the lateral margin of the foot and the developed weakness of dorsiflexion of her left foot. This became worse for a period of about 2 weeks and then remained stationary. She was greatly incapacitated at the time of her admission 5 weeks after the delivery. There was no sphincter

disturbance and nothing of import in the past or family history.

On examination the patient was co-operative and intelligent. There was no lateral tilt of the spine but the normal lordosis was obliterated. Mobility was diminished in the lumbar region—especially flexion and lateral tilting to the right. Straight leg raising was reduced to 45 degrees on the left and 75 degrees on the right. Both legs could be raised to 65 degrees when dropping the right leg caused an increase of pain. There was atrophy of the left buttock and hamstrings as well as all the muscles below the left knee. Eversion of the foot was paralyzed and dorsiflexion greatly weakened. Some weakness of inversion and plantar flexion was also present. Sensory examination showed a diminution of tactile sensibility and a hypesthesia in the first sacral dermatome. The left ankle jerk was diminished. A ray examination showed a definite displacement at the symphysis so that one pubic bone was higher than the other. There was no abnormality in the lumbar spine. Lumbar puncture was not carried out, and a diagnosis of a protruded lumbosacral disc was made. At operation a very large protrusion was found at and the first sacral nerve on the left was greatly swollen. The weight of disc tissue removed was 8 grams. Following operation there was an immediate improvement of patient's pain and a steady improvement of muscular power. When seen 6 months later she was well in every way and a steady improvement of her trouble being that extension and dorsiflexion of the left foot were still weaker than on the right.

Case 3 Mrs E. P. aged 33 years came to hospital in January 1943 complaining of pain in her right leg. She stated that 2½ years previously while carrying out her work which entailed lifting heavy weights she suddenly developed low back pain. Owing to the persistence of this pain she had been treated in a plaster jacket for some 4 months and afterward wore a leather jacket. A year after the onset of her symptoms she felt quite well again though her back was liable to ache at times especially during pregnancy.

Nine months before her admission her child was born. Labor was normal no instruments were used and at birth the child weighed 8½ pounds. Three weeks later she got up and there was an immediate return of low back pain soon followed by right sciatica. This persisted unrelieved until her admission. It was of typical distribution until her admission. It was aggravated by exercise and straining and the patient had got up at night to "walk the pain off." There were associated numbness—numbness of the calf and tingling over posterior thigh calf and sole. She noticed too that the right leg was definitely weaker than the left so that she stubbed her toes and the ankle kept doubling under. There was no micturition disturbance and the past and family history revealed nothing of significance.

Maternal obstetrical paralysis in the distribution of the femoral nerve It has been mentioned that in some cases of maternal obstetrical paralysis the femoral nerve has been involved. It is impossible for such a lesion to be due to compression of the nerve by the fetal head—unless one assumes that in such cases the nerve has an origin and course unknown to anatomists. The occurrence of signs in the distribution of the femoral nerve is readily explicable on the basis of an intervertebral disc protrusion. In a personal series of such protrusions there are now several in which the clinical picture is that of a so called anterior crural neuritis that is pain on the anterior aspect of thigh and subcutaneous surface of the thigh and weakness of the quadriceps. Examination shows a wasted weak quadriceps of hypaesthesia or absent knee jerk and an area of hypaesthesia and hypalgesia on the anterior aspect of the thigh and leg. In these patients the protrusion is at a higher level than the usual. It may be between the 3d and 4th lumbar vertebrae or at the interval above this. The occasional occurrence of a paraplegia after labor can be readily accounted for by the occurrence of a very large disc protrusion such as that represented in Figure 2. One patient in the series of 120 had a protrusion of this type and had evidence of a complete lesion of the cauda equina.

DISCUSSION

It has long been recognized that alterations in the structure and mobility of the pelvic joints occur during pregnancy. In modern times understanding of this fact has been augmented by the work of clinicians radiologists and endocrinologists. In pregnant women the increase in the mobility of the symphysis pubis sacroiliac joint, and sacro-coccygeal joint has been observed clinically and indeed the Walcher position was introduced in an endeavour to utilize this mobility and thus to facilitate delivery in cases of contracted pelvis.

The pelvic joints have been subjected to x ray study and careful measurement with varying results. Roberts (1934) has made a series of measurements and comes to the conclusion that during pregnancy there is an

average increase in the width of the two sacroiliac joints of 1 millimeter. Further he has found that the average increase in the width of the symphysis pubis amounts to about 2 millimeters. Ahramson Roberts and Wilson (1934) have carried out a similar investigation on the symphysis pubis and conclude that while the average increase in symphyseal width during pregnancy is 3 to 4 millimeters in 25 per cent of individuals the increase is greatly in excess of this figure. The authors state that the change begins to develop in the first half of pregnancy and does not progress during the last 2 months. They point out that this relaxation of the pubic joints may give rise to disability and describe a group of 30 cases with symptoms which they regard as being due to increased mobility of the pelvic joints. Young (1940) also describes a group of cases in which he considers symptoms arising during pregnancy to be the result of excessive relaxation of the pubic and sacroiliac joints.

The cause of these changes in the pelvic joints of women has not been decided with certainty. But in lower animals it has been demonstrated to depend upon an endocrine factor. A substance which has been named relaxin has been demonstrated in the corpora lutea and serum of certain pregnant animals (Hisaw 1927). When injected into female guinea pigs during estrus rapid and marked relaxation of the symphysis pubis takes place. A similar substance has been found in the serum of women during the early months of pregnancy (Abramson Hurwitz and Lesnick 1937). These authors suggest that it is responsible for the characteristic joint changes in women. Indeed it would be difficult to explain the changes on any but an endocrinological basis since they begin to appear early in pregnancy. It is also difficult to understand how the action of a joint relaxing hormone can be restricted to the pelvic joints. It seems likely that other joint tissues would respond to the hormone and it is here suggested as a possibility that changes may be induced in the lumbosacral and other intervertebral joints. It is possible that such changes may be responsible for the fact that in a series of women who had been pregnant and who were later

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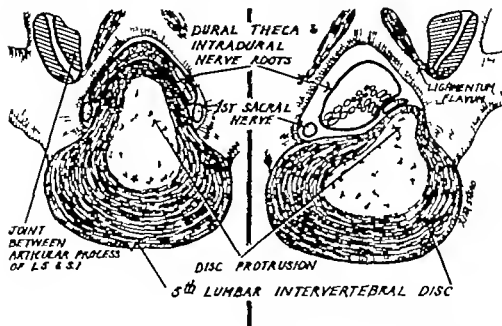


Fig 2 Diagrammatic drawing of a section made through the lumbosacral intervertebral disc. In drawing at left, a large protrusion has occurred, all the related nerve roots—intradural and extradural—are injured and a complete cauda equina syndrome results. In drawing at right, the common type of protrusion is illustrated. The dura and intradural roots are displaced and the effects of the protrusion are confined to the single related extradural nerve which is stretched

that in this patient a great increase in size of the disc protrusion occurred rapidly. This produced what amounted to an almost complete physiological section of the related extradural nerve and probably neighboring nerve roots on the left side were also injured; his pain was therefore eased but paralysis and sensory loss took its place. These neurological signs show evidence of improvement only after 4½ months. This is to be attributed to degeneration of nerve fibers following severe injury at the time of the rapid enlargement of the protrusion and it is thought that complete motor and sensory recovery can occur here only if and when regeneration of these fibers occurs. Finally it is believed that a disc protrusion of type (as regards size and rate of development) intermediate between the two just described will be productive of the syndrome of pain and paresis which syndrome includes the 4 cases of maternal obstetrical paralysis described in this paper.

These observations point to certain therapeutic conclusions. In the first place it would seem that changes in the lower intervertebral joints in pregnancy and the puerperium render them less fitted to withstand strain. From the

point of view of prophylaxis of low back and sciatic pain the strains of heavy work would appear to be contraindicated at such times. Second it is obvious from the literature and from personal experience that spontaneous cure of maternal obstetrical paralysis frequently occurs. However it is also clear from the cases which have been reported in the past that recovery may be slow and incomplete. The 4 patients whose case histories have been given had been severely incapacitated and in 3 of them the incapacity was of considerable duration. Operation will be indicated when the motor disturbance is severe and persistent even if pain be slight. On the other hand severe sciatic pain which does not respond to rest, may indicate operation when objective neurological disturbance is mild. In cases which fall into either of these groups treatment by excision of the disc protrusion can be confidently recommended. In other cases with subjective and objective disturbance of less severity a conservative attitude should be adopted. This will imply rest in bed for pain and splinting together with daily exercises and electrical stimulation for parietic muscles. If disability persists after an ade-

THE RADIOGRAPHIC EXAMINATION OF THE ANKLE JOINT INCLUDING ARTHROGRAPHY

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THE radiographic examination of any joint is too often thought to be complete when clear outlines of its constituent bones are produced on an x ray film. It is clinically certain that ligamentous damage is as serious as bony injury and as radiologically certain that further amplification of x ray technique can demonstrate ligamentous injury. The radiological principles which apply to the ankle are equally applicable to any other joint and should be extended to them. These methods of examination we suggest are necessary before the full information which it is radiologically possible to obtain about a joint has been obtained. There is no suggestion that it is necessary in every case to employ the full technique but certain groups of cases should be submitted to modified forms of examination. It is the intention of this article to concern itself with these groups and the method of examination rather than to give a summary of the radiographic appearances of the multifarious lesions of the ankle.

For accurate radiography of the ankle we employed supplementary to the usual views (1) plain radiography in a standard position compared with a similar film of the opposite side for investigation of the syndesmosis (2) radiography under strain (sometimes described as radiography in the 'position of deformity') The joint was radiographed under a strain appropriate to the ligaments being investigated and supplemented by comparable pictures of the opposite ankle under similar strain (3) arthrography—with a diiodone compound

Of these methods radiography under strain gave the most valuable information and to obtain comparable films of both ankles penitral anaesthesia was employed in preference to local anaesthesia (Hughes 1942)

From an E. M. Hospital.

Positioning The radiographs were taken in four projections but each case was treated individually and in some instances one or two positions were omitted. In positioning the ankle joint some difficulty is experienced in obtaining standard positions as in the normal joint the asymmetry of the part leads to small deviations from accuracy. The position of the foot is not a correct guide as in plantar flexion it may take up many positions in relation to the ankle owing to inversion and eversion and even in full dorsiflexion this still holds true although to a lesser degree. Further more there are no landmarks in the ankle region for obtaining a true anteroposterior view. These difficulties are exaggerated in the injured ankle because of the inflammatory swelling which to some extent obscures the malleoli. For accurate radiography the knee was placed in the true anteroposterior position and the leg rotated to obtain the desired position.

The four positions used were as follows—
a. Anteroposterior 10 degrees, internal rotation. This position is useful in arthrography for showing leakages around the malleoli and tibia and fibula and downward into the peroneal tendon sheaths.

b. Anteroposterior 30 degrees internal rotation. Films were taken of both ankles in this position as it is the optimum projection to show the width of the tibiofibular syndesmosis. The foot is dorsiflexed. A simple support in the shape of a prism with triangular ends bearing angles of 30 degrees at their bases was made by one of us (J G B) each foot in turn resting on one side of the prism. In practice if the head of the first metatarsal and the medial malleolus are placed against the prism with the foot in dorsiflexion a fairly accurate standard position is obtained and the films of both sides are comparable. Thus

position shows extensions of the medium into the tibiofibular joint and escape of the medium in cases of rupture of the ligaments of the syndesmosis (Fig 4 a)

c A lateral or medial projection with the central ray passing through both malleoli so that they are superimposed (bimalleolar view) This is the best position for showing extensions of the joint cavity anteriorly and posteriorly The subtaloid joint is very well shown

d Lateral with the ankle rotated to throw the fibula behind the tibia (lateral view) This position in some cases shows the extension into the tibiofibular joint better than b and is useful in cases of fracture of the posterior tubercle of the tibia.

It will be noted that b and c are at right angles to each other and a and d almost at right angles A comparison of a and b will show if extensions upward in the soft tissues lie slightly in front or behind the malleoli

The problem of diastasis of the tibiofibular syndesmosis will not be completely solved by accuracy of positioning alone owing to individual variation from foot to foot This prevents identical films being obtained and thus destroys the absolute accuracy which is necessary if separations measured in millimeters are to be taken as significant One point, however is worth emphasizing It has been stated by Bromer and others (Ashhurst and Bromer 1922) that in no circumstances is a clear space seen between the tibia and fibula, in the normal foot and such appearance is to be taken as diagnostic of diastasis We have several cases on record in which there is a visible space between both bones at the syndesmosis on either side Its presence is due to the shallowness of the tibiofibular groove and is best shown by the use of the 30 degree inverted position The best evidence of diastasis in doubtful cases is obtained first by accurately comparable radiography in 30 degrees of inversion of both ankles, which may show a significant widening of the interspace This is supplemented by radiography with the foot externally rotated and dorsiflexed which shows a further widening of the interspace and finally if the lesion is suspected to be in complete by arthrography

Radiography under Strain Of the simple methods of investigation this method has provided the most useful information in our hands The fact that 4 to 5 per cent of normal people show a relaxation of the fibular collateral ligament allowing rotation of the talus of both ankles on inversion of the foot renders comparable films of both ankles necessary when the position of inversion is used (Figs 5 a, b and c) We have found no similar ligamentous relaxations occurring normally which affect the other positions of strain

The varieties of strain used and cases for they are of value may be summarised

1 *Inversion*—(tibial flexion) of the hind foot Used in cases of suspected damage to the fibular collateral ligament and its most frequently injured fasciculus the calcaneofibular band This commonly shows a rotation of the talus of from 5 to 35 degrees. Usually a rotation of 10 to 15 degrees is found this is secondary to a rupture of the calcaneofibular fibers. If the rotation is greater than this anterior fibers of the capsule of the joint on the external side and the anterior talofibular ligament are torn If the rotation exceeds 45 degrees the posterior talofibular ligament is also damaged It is difficult to state whether it is completely torn as its attachments leave it considerable mobility Corresponding fibers of the posterolateral aspect of the capsule are of course also torn (Figs. 1 a and b)

2 *Eversion* This is used for suspected rupture of the deltoid ligament In rupture of the anterior fibers (partial lesions) a rotation of 10 degrees may be permitted In complete lesions a 35 to 45 degree twist of the talus occurs (Fig 2)

3 *Plantar flexion* In hyperextension injures the anterior fasciculi of both collateral ligaments may be torn In such a case the lower surface of the tibia and the upper surface of the talus lose their congruity This lesion is a common cause of bimalleolar signs of sprain with a negative radiograph The bimalleolar radiograph is used (Fig 3)

4 *External rotation of the foot* This is used in cases of doubtful diastasis and results in opening up the syndesmosis. The anteroposterior radiograph in 30 degrees of inversion is used (Figs. 4 a and b)



Fig. 1



Fig. 3

Fig. 1. Radiograph under inversion strain. a, left, Normal ankle. b, Twenty degree rotation of talus, associated with rupture of the calcaneofibular ligament.

Fig. 2. Radiograph under eversion strain. a, left, Rupture of deltoid ligament. b, The same case showing healing in 7 weeks.

Fig. 3. Radiograph in plantar flexion showing rupture of the capsule anteriorly and rupture of the an-



Fig. 2



Fig. 4

terior fibers of the deltoid ligament which accompanies severe first degree external rotation fractures of the fibula.

Fig. 4. Radiograph under external rotation strain. a, left, Normal view in 30 degrees internal rotation, showing tibiofibular syndesmosis of sound ankle (left). b, View in 30 degrees internal rotation of second degree abduction fracture with diastasis, showing opening of syndesmosis under external rotation strain (right).

The essential importance of this method is the distinction between the sprains and complete ligamentous rupture. The more often it is carried out the more surprised one will be to discover complete ruptures with the minimum physical signs. In cases with bilateral relaxation of the fibular collateral ligament it is necessary to distinguish recent from old lesions because the presence of this abnormality makes the determination of the degree of damage clinically impossible. We would also like to draw attention to the significance of the frequent occurrence of severe pain over the anterior tibiofibular ligaments. The extensive hemorrhage around the fibula in both cases results in the damaged ligament being diagnosed as lying below the position of maximal pain. In our series this resulted in numerous inaccurate diagnoses. The fact that pain occurs over the anterior tibiofibular ligaments is due to the strain on the syndesmosis produced by the rotation of the talus around a horizontal axis forcing apart the sides of the tibiofibular mortice. This is permitted by the tearing of the calcaneofibular ligament. The

anterior tibiofibular ligament being the tighter of the two ligaments of the syndesmosis is first sprained and being subcutaneous is easily affected by digital pressure. The calcaneofibular ligament is overlain by the fibula and less accessible to the touch.

The four varieties of strain enumerated were also used in cases of fracture in which it was felt desirable to obtain further information concerning ligamentous damage. An accurate analysis of the severity and distribution of the bruising and the radiological appearances enable one to deduce this clinically if one is familiar with the mechanism of fracture. Investigation did serve to emphasize the fact that the common external rotation fracture of the lower end of the fibula may be merely subperiosteal show slight displacement or may be accompanied by considerable displacement with tearing of the anterior portion of the capsule and anterior fibers of the deltoid. The treatment of the fracture must thus be adapted to the ligamentous damage and no single method is satisfactory in all cases.



Fig 5 Bilateral hypermobility of the ankle joint. Rotation of talus on both sides in inversion condition met with in 4 per cent of uninjured ankles. The degree of rotation varies from 5 to 5 degrees. (Without anesthesia) a, Photograph of the right ankle showing normal inversion of the sole of the foot. b, The right ankle. c, The left ankle.

ARTHROGRAPHY OF THE ANKLE JOINT

Arthrography has not been developed in the British Isles to the same extent as in America and the Scandinavian countries in spite of a proved if limited field of usefulness. There is still a prejudice against the conveying of infection by puncture of a joint cavity in spite of the harmless results following the thousands of injections which have been made. In those cases and others not reported here in which the medium was not satisfactorily introduced into the joint and in arthrography of the knee no ill effects either local or general have been observed to follow the procedure. The investigation of the ankle joint was undertaken in an attempt to solve the complex mechanical problems presented by ankle injuries, by getting further information concerning ligament rupture. After it had been carried out in a series of typical cases the procedure was then used only in those in which added information was required.

We do not pretend that the method has a wide sphere of use. In our experience more useful information is gained by radiography of the joint under strain during general anesthesia. The results of arthrography confirming the findings of careful observers who have made postmortem examinations on recently injured ankles are at least interesting comparative evidence and bring home some essential and often forgotten points. In a few cases the method is of diagnostic value and gives information otherwise unobtainable particularly in questions of partial separation of the tibiofibular syndesmosis.

Technique. As a contrast medium 'pyelonal' brand of diodone was used. The amount used was 3 cubic centimeters which was increased to 6 cubic centimeters in some cases with marked effusions of blood into the joint. The introduction of such a small amount into a joint even assuming it entered the circulation through a fracture can have no general systemic effects of importance compared with those which might follow 20 cubic centimeters injected intravenously in pyelography. The local reaction is primarily important and no ill effects were noted there were no complaints of pain no swelling and no alteration in progress which was not attributable to the original injury. This is in conformity with the recognized low toxicity of the drug.

Our cases were all done under general anesthesia, as a preliminary examination under strain was to be made and comparable pictures of the opposite ankle were often required. Pentothal was always employed. After skin preparation the anterior aspect of the joint was painted with iodine and a long fine bore needle was introduced into the joint without the syringe being attached. On regurgitation of mixed blood and synovial fluid the medium was injected. In older cases, no fluid regurgitated and it was necessary to rely on the sense of touch alone. Entering through the capsule and contact with the smooth surface of the talus can be appreciated. Striking the joint cavity is not easy if judged from the superficial nature of the joint and at first some injections below the anterior tendons on the dorsum of the foot were made.

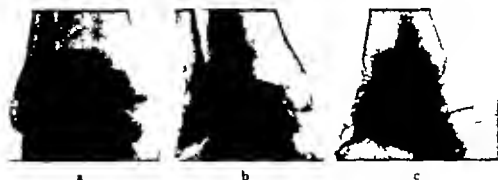


Fig. 6 The normal arthrograph. a, Position 10 degrees internal rotation. Showing the usual rounded extension under the anterior portion of the deltoid ligament. b, Position 30 degrees internal rotation. The medium in the synovial extension between the tibia and fibula shows poorly (Compare Fig 9b). c, Position bimalleolar. Note the indentation made by the tendon of flexor hallucis longus in the posterior aspect of the joint, and the extension of the capsule down the neck of the talus.

The injection can be made to either side of the ankle the needle being entered at the level of the lower surface of the tibia just inside the anterior margin of either malleolus. The posterior approach offers greater difficulties and the risk of damage to the posterior tibial artery and nerve if the posteromedial route is employed. In practice we used either approach entering the needle on the side away from the area where damage was suspected in order to avoid any risk that spilling might confuse the picture. Following the injection the joint was manipulated a few times to diffuse the medium through the cavity. The failure to diffuse into the required area may be responsible for some negative findings which should be positive. These cannot be offset entirely by increasing the amount of medium used as large amounts tend to leak through capsular ruptures and reduce its concentration in the joint at the same time increasing the number of confusing shadows.

Injections were made at any time from 1 to 7 days after injury in recent cases. In these capsular tearing was as readily seen on the 1st as on the 7th day. The reduction in swelling which occurs after a few days rest with the leg elevated simplifies the injection though the more distended the joint capsule the more readily the joint is entered. No observations were made as to the length of time the contrast material persisted into the joint but satisfactory arthrographs were obtained up to half an hour after the injection though it is obvious that the sooner after the injection the

radiograph is made the better the contrast and definition.

The normal arthrograph. No uninjured ankle was examined and thus account is derived from forming a composite picture from the various normal parts of damaged ankles. The joint space shows as a thin line between the upper surface of the talus and the lower surface of the tibia. The line extends downward in the anteroposterior view to just below the malleoli rather lower on the outer side. In one case a small fringe of synovial membrane indented the medium on the inner side below the medial malleolus. The anterior sac of the synovial membrane extends forward along the articular surface of the talus and slightly beyond. An extension of this sac may show on the anteroposterior film just below the medial malleolus where it bulges out medially to the tibialis anticus tendon. This anterior sac is best shown in the true lateral projection (c) but in the anteroposterior view furrows due to the extensor tendons may be seen. There is a small posterior sac also best seen in view (c) which is frequently notched by the tendon of the flexor hallucis longus and may show other tendinous indentations. This sac is always situated above the posterior process of the talus (or the os trigonum if present) and must be distinguished from the posterior sac of the posterior talocalcaneal joint which extends backward along the upper surface of the calcaneus and is below the lateral tubercle of the posterior process of the talus (Fig 10). This latter sac extends very much further posteri-



Fig. 7. Left, Arthrograph showing rupture of calcaneofibular portion of the fibular collateral ligament and the narrow neck of escaping fluid between the bone and the peroneum and its attached ligaments (compare Fig. 1).

Fig. 8. Arthrograph (bromellar view) showing escape of the contrast medium anteriorly (compare Fig. 3).

only. Commonly in cases with good filling a small extension upward is seen between the tibia and fibula. This is most clearly seen in b and sometimes in d positions.

Stereoscopy may be of value in some cases to elucidate a particular shadow, but we do not feel that its employment as a routine procedure is worth the extra time and films expended.

The abnormal arthrograph. Arthrography of the ankle demonstrates a number of anatomical facts on the living in a ready and satisfactory manner.

1. *Site of rupture of ligaments.* The escape of the contrast medium from the joint around the lower end of the fibula outlines perfectly the shape of the bone and usually runs a short course with parallel and even borders before expanding into the subcutaneous tissues over



Fig. 9. Left, Arthrograph (bimalleolar low) showing communication of the ankle with the subtaloid joint and extension into the flexor hallucis longus sheath, and the loose sac of the subtaloid joint extending posteriorly on the surface of the calcaneus.

Fig. 9. Arthrograph of the ankle (lateral view) showing the extension of the medium up and between the tibia and fibula at an abnormal height, suggesting partial dislocation.



Fig. 9. a, left, Arthrograph showing extension of medium into the peroneal tendon sheaths and into the sheath of flexor hallucis longus. b, Same case showing the extension of the medium into the synovial cavity of the tibiofibular syndesmosis.

the malleolus. This narrow even band represents filling of the space between the torn fibroperosteal attachments of the ligaments and the bone—well recognized at operation or postmortem as the common site of ligamentous rupture (Fig. 7). We were unable to demonstrate any case in which the medium escaped through the ligament. The common variant is transverse fracture of the malleolus and here the medium escapes through the fracture line. We regard it as highly improbable that a sprain ever results in ligamentous lengthening beyond its elastic limits, i.e. represents scattered ruptures of fibers through the ligament with no break in its contour.

A sprain is due to a partial separation of the fibroperosteal attachment of the ligament which alone can account for the rapid and profuse hemorrhage which accompanies even minor sprains.

2. *Rupture of the capsule of the joint.* This may shed further light on the severity of injury. Thus in first degree external rotation fractures of the fibula the talus and lower fragment of the fibula may rotate backward thus tearing the anterior capsule of the ankle and finally the anterior fibers of the deltoid ligament. Examination of the amount and site of the hemorrhage allows this to be deduced clinically and it is confirmed by arthrography (Figs. 3 and 8).

3. *Anatomical communication of the ankle joint with the tendon sheaths of the peronei.* tibialis posterior and the extensor hallucis longus have been recognized as occurring normally (Fig. 9). Their frequent occurrence in ligamentous rupture is well demonstrated

by arthrography. The peroneal sheaths are involved in every case of rupture of the fibula collateral ligament and in almost every case of rupture of its most commonly injured portion, the calcaneofibular ligament. It is impossible from our examination to deduce the incidence in normal ankles but this is obviously fairly high.

4 Communication between the ankle and the subtaloid joint is also of recognized normal occurrence. It occurred at times in our series in joints in which it was not specially likely to be produced by injury which suggests the frequency of its normal occurrence. It is particularly common in cases of partial or complete rupture of the fibular collateral ligament or injury to the lower end of the fibula (Fig 10). It is interesting to note that this joint may be entered by introducing a needle between the fibula and the talus until it strikes the dorsum of the calcaneus.

OBSERVATIONS

The traumatic problems to which arthrography offers some assistance are perhaps of a theoretical nature and not to the taste of a practical surgeon. It does give information which is obtainable in no other manner and it is possible that in a larger series of cases some more interesting and important points would come to light.

1 Diastasis. Complete rupture of both anterior and posterior tibiofibular ligaments can always be determined by accurate radiography without resort to arthrography. In partial diastasis i.e. lesions involving the anterior or posterior tibiofibular ligament alone arthrography offers the only available method of proof. In one case (Fig 11) which would have been regarded as a moderate sprain of the anterior tibiofibular ligament partial rupture was shown to have occurred. To be of value it is necessary that the arthrography be carried out early as the narrow space between the tibia and fibula rapidly fills with clot and blocks the extension of the medium. In certain fractures of the fibula

due to indirect violence applied to the lower end of the bone only the anterior tibiofibular ligament is ruptured and if it is desired to prove this arthrography must be employed. The field of use is rather restricted but in this as in other rare fractures is a valuable source of additional information.

2 Distinction between old and recent lesions. In the hypermobile ankle which has been the seat of old injury and possibly shows some small flakes of bone in the ligaments it may be difficult to determine clinically how much of the relaxation of the collateral ligament is due to recent damage (which will respond to treatment) and how much to the old injury. In such a case arthrography is a valuable method of accurately determining the degree of recent rupture present and so allowing an accurate prognosis to be made.

SUMMARY

- 1 The technique of arthrography of the ankle is described.
- 2 The appearances of the normal arthrograph of the ankle are shown.
- 3 The anatomical features of ankle injuries demonstrated by arthrography are enumerated.
- 4 Its value in the supplementary examination of ankle lesions is small and confined to rare lesions: partial diastasis and the distinction of old and recent injury.
- 5 More information of diagnostic value can be obtained by radiography of the joint under strain.
- 6 The appropriate cases in which strain should be employed and the types of strain used are enumerated.
- 7 The findings are based on 25 cases examined by arthrography.

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THE EXACT ANATOMY AND DEVELOPMENT OF THE LIGAMENTS ATTACHED TO THE CERVIX UTERI

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A GOOD deal of uncertainty and conflict of opinion exists as to the exact attachment and development of the ligaments connected with the cervix of the uterus and their relationship to surrounding structures. As the ligaments are of much importance in gynecological and obstetrical work it would seem that an understanding of their exact anatomy and development would be of great help in planning operative procedures in this field.

Some of the reasons of misunderstanding may be attributed to (a) lack of unanimity in description in the various textbooks of anatomy and the diverse methods of anatomical demonstration (b) difference of opinion among gynecologists and obstetricians both as to their surgical anatomy and to their function (c) individual variability in morbid and in normal cases.

Because of the extensive material involved this study will be divided into three parts.

Part I The lateral ligaments of the cervix uteri (Mackenrodt)

Part II The pelvic fascia with its embryological development

Part III The clinical significance of the pelvic fascia in obstetrics and gynecology

LITERATURE

The importance of the connective tissue in the subperitoneal space was almost completely overlooked by the older anatomists.

Virchow originally defined the parametric tissues as the loose fatless connective tissues with abundant blood vessels and lymphatics which surround the lower part of the uterus and the upper part of the vagina.

With the development of gynecology came a keener interest in these fascial structures.

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Acknowledgment and appreciation are expressed to the Cooper Fund of McGill University for a research grant in aid of this work, and to Professor C. P. Martin for criticism and advice during preparation of this paper.

A very stimulating paper on the normal and abnormal positions of the uterus appeared in the *Archiv fuer Gynaecologie* in 1895 by Alwin Carl Mackenrodt under the caption "Ueber die Ursachen der normalen und pathologischen Lagen des Uterus." His rise to fame was interesting. He was born November 12, 1859 and died December 29, 1925. Mackenrodt was the son of a landowner near Nordhausen (Hara) who insisted on all his three sons studying theology. Alwin Carl soon defied the old man, hung theology on a peg and studied medicine, graduating at Halle with a thesis on *Chloasma uterinum*. He worked in Volkmann's surgical clinic, started practice in 1886 at Strassfurt and at once made a wide reputation by saving many children by tracheotomy in a severe diphtheria epidemic. In 1890 he went to Berlin as gynecological assistant to August Martin, and started his own private clinic in 1895. Though he refused official connection with the university his success as a teacher and operator earned him the title of professor in 1904.

A bibliography appended to his obituary lists 73 of his publications, one of which has stood the acid test of time and still bears his name, namely that related to the present work, in which Mackenrodt summarizing previous work on the constituents of the tissue at the base of the broad ligament added his own findings. In this paper Mackenrodt emphasizes the action of a band of connective tissue which he calls the *ligamentum transversale colli*.

Mackenrodt defined it as follows:

At the end of the vertebral column, the pelvic fascia can be seen to give rise to a strong band which is inserted into the lateral wall of the collium uteri. The small weak center of areolar tissue between the folds of the peritoneum, in the broad ligament, is sharply to be defined from this fibrous band, which begins at the internal os, and springs from the pelvic fascia. We speak, therefore, of the broad ligament only as the part covering the uterine body and call



Fig. 1. Lateral ligament of cervix uteri (Mackenrodt) viewed from above presenting superior surface (Probe under ureter)

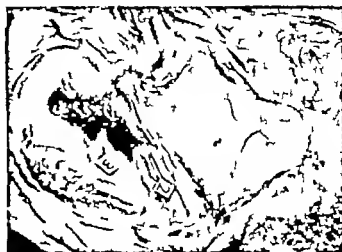


Fig. 2. Right lateral cervical ligament (Mackenrodt) seen from above and behind. Uterus deflected obliquely to left, uterine artery anteriorly. Ureter in position. 1 Superior surface. 2 Posterior surface. 3 Levator ani fascia.

the lateral band to the collum the ligamentum transversale colli. It is the chief means of fixation of the uterus and carries in its upper margin the chief artery the arteria uterina. Smooth muscle fibers extending laterally from the cervix are found constantly in this region.

As a sort of continuation downward of the ligamentum transversale colli short fiber bundles spring from the fascia of the levator ani and are attached to the connective tissue sheath of the lateral wall of the vagina, giving it a broader hold. These fibers run in front of the ischioanal fossa. As a result of this firm lateral fastening of the vaginal canal to the pelvic fascia the mobility of the lateral walls of the vagina is much less than that of its free anterior and posterior walls and further the cross-section of the vagina is fairly constant and in the resting state the anterior and posterior walls are in contact. The well

known H-shaped folding of the vagina here finds its explanation.

The other features of his paper are as follows. He investigates the factors which hold the uterus in its normal position of anteversion and antelexion. He described the closure of the anovaginal cleft by pelvic fascia which sends firm bands to the cervix and vagina. He describes the cervix as being held fast in its embryological position by ligaments, and the normal anteversion and antelexion takes place by the bending of the cervix—not the corpus. The uterine body is kept in position by its own weight and intra abdominal pressure not by ligaments. He supports this lat



Fig. 3. Anterior layer of left Mackenrodt ligament seen from above and in front. In the picture it appears as if detached from the vagina, but actually it is firmly adherent to the lateral vaginal wall. Bladder—front end retracted.



Fig. 4. Specimen viewed from in front and above. Uterus has been deflected to right. Angular crossing of uterine artery over the left ureter. Ureteric fascia blending with vesical fascia.

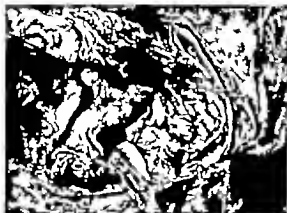


Fig. 5. Right anterolateral view of the specimen after deeper dissection. Lateral cervical ligament (Mackenrodt). Uterus has been deflected to left. Uterine artery crossing ureter at right angles. Lateral margin of the superior surface.



Fig. 6. Seen directly from above—lateral cervical ligament (Mackenrodt). Deeper dissection. Uterus to left of midline. Uterine artery displaced posteriorly, ureter anteriorly, exposing superior and anterior surfaces of ligament. Cleft in superior surface showing smooth muscle fibers.

ter finding by stating that he has often in the course of a laparotomy resected portions of the round ligament and retroverted the uterus experimentally but that he has always found in subsequent examination in the case of a healthy nonpregnant uterus that the organ would right itself and be found anteverted again.

While no doubt Mackenrodt did not lack adult material in his private hospital all of his descriptions with the exception of one are from fetal pelvises which at their best would not

lead to the fullness of description as seen in the adult pelvis. Mackenrodt perhaps, even underestimated the ligament in this respect.

There is considerable diversity of opinion on the anatomical topography and function of the ligaments described by Mackenrodt. Discussion still exists concerning the part which



Fig. 7. Seen from above and in front. Deperitonealized, bisected, uterovaginal fascia. Vagina is packed and bulging. 1. Smooth muscle fibers. 2. Wing-like reflected levator ani fascia. 3. Uterovaginal fascia. 4. Ureteric fascial sheath with severed ureter. 5. Ureter intact. 6. Perivaginal fascia.



Fig. 8. Seen directly from above. Lateral cervical ligament (Mackenrodt). Uterus and uterine artery deflected posteriorly. Ureter in position. 1. Superior surface. 2. Smooth muscle fibers. 3. Cervicovaginal junction.

these ligaments and their juxtaposed fascia play, in the basis of uterine support. Many authors consider the pelvic floor to be the main supporting structure.

Textbooks are not clear on the subject nor is a great deal of current clinical teaching any more explicit. Modern textbooks in anatomy have been meager neglectful or vague in their descriptions of Mackenrodt's ligament. Textbooks in gynecology and obstetrics while considering the fascia have been content with mentioning Mackenrodt's ligament as a part of the general fascial diaphragm without making any effort to describe it in detail, or have repeated one another's descriptions with out personal verification. Leading articles of recent date have featured the fascia in beautiful semidiagrammatic style, while others have neglected mentioning this important ligament or depreciated its value.

From a review of the literature it is evident there is still divergence of opinion as to the existence and exact arrangement of this ligament. Anatomical textbooks have been content to recapitulate the earlier descriptions of the pelvic fascia. Recent obstetrical text books and papers review its importance in the light of clinical application. Gynecological textbooks and papers in earlier years maintained the concept of this ligament as a purely suspensory apparatus while more recently the vascular pedicle as an integral part of Mackenrodt's ligament has been emphasized. With the object of demonstrating this ligament in a more striking and convincing manner several special dissections were made.

MATERIAL AND TECHNIQUE

In this contribution accounts of anatomical dissection of cadavers at different periods of life are presented two female bodies of 79 and 88 years respectively two pelves in midsexual life one of 25 and one of 30 years and fetal bodies at various stages of intrauterine life from 4 1/4 months to term.

The dissected material was injected with a solution of glycerine alcohol phenol formalin and potassium acetate and was preserved during intervals of dissections either immersed in injecting fluid or kept dry in the vault. Some of the fetal pelves were preserved

in 10 per cent formalin others in absolute alcohol. Thus one was able to view both the moist and dry dissections. Plasticine models to scale were made from dissected material.

By entering the clear space and further separating the anterior and posterior leaves of the broad ligament more caudally the anterior and posterior surfaces of the lateral ligament are readily brought into view. Figure 1 shows the ligament exposed in this manner and viewed from above presenting the superior surface. From the lateral to the medial aspect it can be noted that the uterine artery crosses the ureter at right angles over the extreme lateral margin of the ligament and then courses medially in the line of cleavage between the lateral ligament and the vesical fascia. More medially a fascial reef extends from the posterior to the anterior leaf of the broad ligament. It crosses the lateral ligament obliquely and is attached to its upper surface. This reef is instrumental in producing the angular deflection of the uterine artery and also in deflecting and helping to anchor and maintain the ureter in its lateromedial approach to the vesical trigone. This feature is of inestimable clinical significance as otherwise the ureter would encroach upon the cervix and would be injured more frequently in the operation for total hysterectomy. Thus in reality the lateral ligament of the cervix uteri lies below the uterine artery and ureter.

Turning now and looking at the ligament from a posterior view (Fig. 2) it can be seen that the posterior surface is the largest of the three surfaces and blends with the levator ani fascia. The lateral border of this surface descends from the level of the levator ani white line and proceeding in a medial and caudal direction blends with the pelvic layer of the levator ani fascia to a point within a few millimeters of the anovaginal cleft. A particularly firm attachment is present at the ischial spine this is a fixation point. In the diagram the index finger of the gloved hand is placed on the spine. Laterally attenuated fibers of this surface are continued upward on the pelvic wall to blend with the firm connective tissue which encloses the hypogastric vessels. Thus it will be noted that the lateral fascial attachment of this surface blends with the



Fig 9. (Dra. Ing.) Clear space.

lateral pelvic wall over a considerable height giving this ligament a very strong postero-lateral attachment and perch which acts as a wide lateral pliable fixation span. This latter is of fundamental value clinically—when one considers the functions of the ligament from a supportive viewpoint gynecologically or its clinical value in the physiology of parturition. A very definite foramen is formed at the mediocaudal aspect of this posterior surface where its fibers blend with the fascia of the levator ani which is attached to the lower lateral wall of the vagina (Fig. 2).

From the anterior aspect as viewed in Figure 3 it will be noted that the medial fibers of this surface fuse firmly with the fascia on the lateral wall of the upper third of the vagina, while the lateral fibers blend with the visceral fascia of the levator ani muscle. This is the shortest of the three surfaces, because there is an acute rise in the levator ani muscle in its pubococcygeal fibers in this area.

OBSERVATIONS FROM STUDY

The lateral ligament of the cervix uteri (Mackenrodt) is therefore a well defined fascial connective tissue capsule, which in transverse sections has the form of an inverted U originating from the anterior superior and posterior marginal walls of the supravaginal cervix with attachments to the vagina. It consists of a superior anterior and posterior surface.

The superior surface (Figs. 1, 4, 5) The fibers passing posterolaterally in a gentle curve insert into the levator ani white line (White line of the pelvic fascia for all practical purposes considered conjointly.) Guided obliquely and medially over the lateral margin of this surface by an oblique fascial band (Fig. 1) from the posterior to the anterior leaf

of the broad ligament, the ureter runs toward the vesical trigone about a half to three quarters of an inch from the lateral cervical margin on the right side and about half an inch on the left side (Fig. 5). At the extreme lateral margin of this surface the uterine artery crosses the ureter at right angles and following the anterior margin traverses the superior surface of the ligament to the supravaginal cervix where it divides into ascending lower uterine segment and cervical branches the latter piercing the ligament.

The veins encapsulated in pelvic fascia are on the posterior aspect of the superior surface. The uterine artery is an individual entity near the anterior aspect of this surface demarcating the line of cleavage between the lateral ligament and the adjacent cervicopubic fascia (Fig. 1).

Toward the lateral third of the broad ligament a fascial laminated sheath spreads obliquely from the posterior to the anterior leaf of the broad ligament. This fascial reef is instrumental in deflecting the ureter and uterine artery to the anterior aspect of the superior surface.

The anterior surface (Fig. 3) This appears usually to be of a thinner texture and has a smaller surface area than the other two surfaces. Its fibers are directed laterally and caudally to terminate in the levator ani fascia. Here the levator ani muscle rises sharply from a narrow line. The upper medial third of the ligament with the anterior border of the superior surface forms an elliptical incomplete hiatus for the passage of the ureter (Fig. 6). The uterovaginal fascia (cervicopubic) blends with this surface (Fig. 7).

The posterior surface (Fig. 2) This is the best defined and largest surface area. Its fibers extend posterolaterally and caudally to blend with the levator fascia. Its most posterolateral extremity is fixed at the sacral spine. Smooth muscle fibers extend from the upper third of the vagina (Figs. 7, 1, 8, a) and insert obliquely into the inferior and medial aspect of the superior and posterior surfaces of the ligament (Figs. 7, 8).

Thus the three surfaces of this ligament enclose a space which in the normal adult contains areolar tissue and smooth muscle fibers.

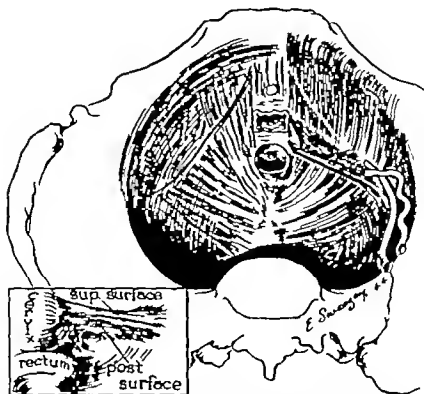


Fig. 10. Semidiagrammatic representation of pelvic floor with right lateral cervical ligament shown in position. (On the left side the fascia has been removed to show the underlying muscles.) At the lateral end of this ligament the uterine artery can be seen crossing the ureter. At the medial end of the ligament the inverted U-shaped outline is well shown. The small insert shows the ligament from behind. Note the hiatus at the lower border of the posterior surface—for further description see text.

Looked at from in front, this space is triangular. The base of the triangle facing caudally and lateralward is formed by the superior layer of the levator ani fascia.

On account of its inverted U-shaped structure the ligament is capable of great expansion by an opening out of its anterior and posterior surfaces and thus is able to meet physiological requirements.

METHOD OF APPROACH (FIG. 9)

The simplest method of approach to expose the lateral cervical ligament is to secure the utero-ovarian ligament, the tube and round ligament, and open the broad ligament completely down to the bottom of the clear space. The anterior and posterior leaves of the broad ligament are then readily separated, exposing the uterine artery and superior surface of the lateral cervical ligament.

Few other structures in the human body have enjoyed such a varied nomenclature.

Among others the following designated titles have been applied: the parametrium (Virchow), the cardinal ligaments (Kock), the vascular sheath (Charpy), hypogastric sheath (Pierre Delbet), the uteroiliac process (Savage), transverse cervical ligament (Mackenrodt), tunica vasorum uteri (Merkel), ligamentum lata, lateral pelvic ligaments, ligamentum transversale colli, the sustentacular apparatus (Bonney), the lateral cervicopelvic ligaments.

The anglicized version, namely, the lateral ligament of the cervix uteri, is a more meaningful and purposeful terminology and in keeping with the principles accepted at Basel in 1895 by the Anatomical Society.

SUMMARY

Figure 10. A well defined fascial ligamentous connective tissue capsule in the form of an inverted U is attached to the anterior superior and posterior marginal walls of the

supravaginal cervix. Laterally and inferiorly this capsule is attached to the levator ani white line and to the levator ani fascia. It has anterior, superior and posterior surfaces.

The *superior surface* presents large veins on its posterior aspect while anteriorly the uterine artery is an individual entity coursing above the fascial surface and marks the line of cleavage between this surface and the vesical fascia.

Toward the lateral aspect a reef of fascia extends obliquely from the posterior to the anterior leaf of the broad ligament above the capsule and deflects the uterine artery anteriorly and helps to maintain the ureter in its lateral position. At the extreme lateral aspect of this surface the uterine artery crosses the ureter at a right angle. The ureter traverses the anterior margin of the surface in a preformed fascial groove.

The *anterior surface* is the smallest of the three surfaces, because the levator ani muscle

rises sharply in this region. The upper part of this surface fuses with the uterovaginal fascia giving the latter a wider "fixation span" while the lower part is attached to the fascia of the lateral vaginal wall. Caudally and laterally this surface is attached to the levator ani fascia.

The *posterior surface* is the largest of the three surface areas. It blends with the levator ani white line and with the levator ani fascia. A foramen or gap is present between the ligament and the fascial fibers passing up from the levator to the vaginal fascia. A triangular space exists between the three surfaces. The base of the triangular space faces caudally and lateralwards being formed by the cranial fascia of the levator ani muscle. In the normal adult this cavity contains areolar tissue and unstriped muscle. Smooth muscle fibers extending from the upper third of the vaginal wall are attached to the superior and posterior surfaces of the ligament.

RECONSTRUCTION AFTER RADICAL OPERATION FOR OSTEOMYELITIS OF THE FRONTAL BONE

Experience in Thirty-eight cases

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THIS paper is a compilation and review of 38 cases of patients who have been operated upon in the past few years for the correction of cranial defects following previous operations for osteomyelitis of the frontal bone. It is a continuation of the series reported 3 years ago by V. H. Kazanjian and J. M. Converse. The authors then discussed the operation for osteomyelitis and also the problem concerned with plastic repair. In this paper no attempt will be made to discuss the problem as a whole or as it relates to osteomyelitis of the frontal bone as the problems have been adequately dealt with by other authors (8, 10, 12, 14, 15, 16).

In the present series the authors were preoccupied with the problem of dealing with the surgical end results of osteomyelitis that is, operation had been done to remove the osteomyelitic bone and the patients had recovered but they were left with varying degrees of scarring and disfigurement. In the least disfigured patient there was found scarring along the lines of incision used to expose the frontal bone in association with a flattening of the supraorbital ridge and forehead from the loss of bone (Case 1, Fig. 6). In the most disfigured patient the defect had been caused by the forehead flaps being permitted to retract and thus to become folded or corrugated. The dura then became exposed and coated with a thin layer of epithelium so that such patients were truly disfigured individuals (Case 2, Fig. 9). The various methods employed in repairing the defects in the latter group of patients, the changes in the form of treatment from that used in earlier cases of osteomyelitis and some of the pitfalls that have been encountered will be discussed.

Various implants have been employed at operation—cartilage, bone, vitallium, tantalum and an acrylic. Each material has its merits, and each one is preferred in specific instances. These materials will be discussed in relation to their value and drawbacks and an attempt will be made to evaluate as a whole the problem of implants.

INCISION FOR EXPOSURE OF FRONTAL BONE IN CASE OF OSTEOMYELITIS

When a surgeon is contemplating operating on a patient with osteomyelitis of the frontal bone, he should choose the incision that will leave the least disfigurement in the case at hand. In the past the operators in our clinic have employed an inverted T incision to expose the frontal bone (Fig. 1) which consisted of a midline vertical cut from the glabella to the hairline and a horizontal cut just above the eyebrows. The incision gives direct exposure of the forehead when the flaps are reflected and an easy approach into the ethmoid and nose. The midline scar is not difficult to repair and may largely disappear. The main drawback to this incision is the distortion which is prone to occur about the brows—a major problem in restoring the normal countenance. Nevertheless it is the incision of choice if the case is one of fulminating osteomyelitis which has not responded to chemotherapy, and in which the wound must be left open for observation. In such a case the resultant scar is of secondary importance.

When the case is one of subacute osteomyelitis or one in which the osteomyelitis has been controlled by drugs, the operator is then justified in planning an operation that will leave the least disfigurement. In such cases the operator can plan to expose the bone, remove the diseased area and return the pericranial flap immediately.

From the Plastic Clinic of the Massachusetts Eye and Ear Infirmary.

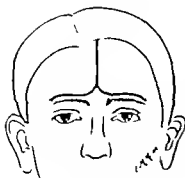


Fig. 1.

Fig. 1. Drawing to illustrate the preferred incision—the inverted T incision with rounded angles—above the eyebrows.



Fig. 2.

Fig. 2. Drawing to illustrate the inverted U incision, which extends from the position just below the ear to the hair line, over to the opposite side.

The incision of choice in such a case is what we call the inverted U incision (Fig. 2). It should start on a level with the top of the ear at the hairline and follow the hairline over the brow to the opposite side. The scalp may then be retracted forward over the face so that the frontal bone, including the supraorbital rims, is exposed as in postmortem dissections. Even the nasal bones and if need be the lacrimal bone may be exposed in this manner. Through this field it is possible to do any of the surgery that may be required for the rectification of the osteomyelitic bone and the disease in the frontal sinuses and the ethmoids.

If the operator believes that the operative field should be under observation for a few days, this is also possible. The flap may be left open and if it is found that the wound is healing properly it may then be closed. This procedure has been tried and found to work satisfactorily.

SELECTION OF TIME FOR PLASTIC OPERATION TO CORRECT DEFORMITY

Before plastic procedures in these post-operative osteomyelitic cases are undertaken it is essential that we select carefully our time for operating. The operator must be sure that the patient is completely free of any infection in the bone, the soft tissues, or in the sinuses which originally were the cause of the infection. The second criterion is to be satisfied that the individual has no evidence of intracranial pathology which might be connected with the original infection. In this particu-

lar the operator should be concerned especially with latent brain abscess. Infection in the soft tissue or in the brain cannot be ruled out until at least 2 or 3 months have elapsed following apparent cessation of all inflammatory reactions. If outwardly there is no evidence of infection the nose should be carefully examined to ascertain the presence of inflammatory reaction or pus, and an x-ray film of the sinuses should be studied for evidence of residual infection. In spite of this care we have encountered encysted pus and have had infection follow in the wake of an apparently aseptic operation. With infection ruled out to the best of one's ability it is then comparatively safe to proceed with the operation.

OPERATION PREPARATION OF FOREHEAD FLAPS

The success of operation depends largely upon the condition of the soft tissues, particularly of the skin and scalp and to a lesser degree upon the size of the bony defect. If the scalp flaps are not sutured together at the time of removal of the bone, contracture always takes place, and there is a great deal of change in the subcutaneous tissues and in the dura (Case 2, Fig. 9). In such a case it is necessary to free the flaps from the dura and to stretch them to the size of their original surface area. The operation may be performed either under local or general anesthesia. It is usually more satisfactory to employ general anesthesia. To facilitate the

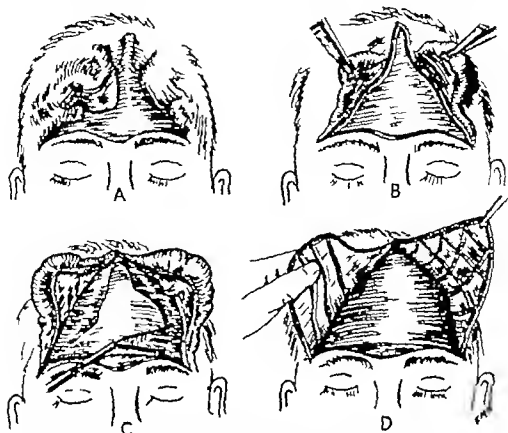


Fig. 3. A, Wound of 3 months after resection of the frontal bone. B Skin flaps dissected back, exposing the surrounding bone superficial epithelium incised. C, Epithelium dissected over the layer of granulations covering the dura. D Incisions carried through subepithelial tissue to permit extension of the skin flaps.

separation of the flaps from the dura and to control bleeding which is usually considerable when the scalp is involved it is advisable to infiltrate the flaps subcutaneously with a solution containing a small amount of epinephrine. Epinephrine acts in a twofold manner: it not only reduces the bleeding but it creates a line of cleavage which makes much easier the separation of the flaps from the dura. Once the flaps have been separated from the dura they are invariably curled upon themselves or corrugated as a result of the contraction of the elastic fibers and scars in the subcutaneous layers. To enable one to return such contracted flaps back to their normal surface-covering area it is necessary to cut through the contracted subcutaneous tissue by crosshatching the under surface with a sharp knife (Fig. 3D). When this procedure is carried out, the skin can be approximated without tension. Should the flaps require much crosshatching it is wise to permit them to heal for from 4 to 6 weeks prior to the graft

ing of any bone. This period enables the vascular supply to this area to become re-established thus improving the chances of the graft to take. At this step it is not only customary to free the flaps but to undermine the scalp over the skull for a distance of 2 to 3 inches beyond the defect thus assisting in increasing the mobility of the parts involved.

In this type of patient there is always an area of dura which is covered with a thin layer of epithelium which has grown in from the edges of the wound and must be removed by sharp dissection. If any of the epithelial cells were left there would exist a potential cyst. Caution must be employed when dealing with the area about the nasofrontal duct; in this area it is easy to enter the nose and to contaminate the field. Should this area be entered it is advisable to swing a flap of tissue from the adjacent structures to cover this defect. Another precaution that must be considered is the ease with which the orbit may be entered when the brow is freed from the

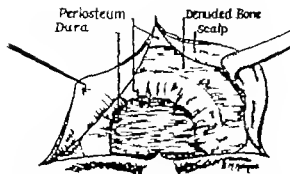


Fig. 4. Illustration showing the periosteum of the frontal bone cut about an inch and a half beyond the margin of the defect, elevated, retracted medially and sutured to the dura.

orbital periosteum. In the majority of these patients, the supraorbital rim together with the floor and posterior wall of the sinus is completely gone, so that in this region the periosteum that forms the outer casement of the orbital contents is in contact with the dura.

PREPARATION OF BED FOR RECEPTION OF GRAFT

If the flaps were closed at the time the osteomyelitic bone was removed or soon following the original operation the stage mentioned may be omitted as the forehead flaps readily cover the defect and there is no epithelium on the dura that requires removal. Our task resolves itself into the preparation of a bed for the reception of a graft or insert.

The flaps are infiltrated as previously mentioned. Incisions are made along the line of the existing scars, and the scalp is separated from the dura by sharp dissection. When the edge of the bone is encountered the scalp is separated from the periosteum for a distance of 2 or 3 inches around the margin of the bony cavity. The periosteum is incised parallel to the edge of the bony defect and about an inch to an inch and a half from it. It is then separated from the bone and brought toward the center of the defect where its cut edge is sutured to the dura with a few interrupted fine catgut sutures. It is left attached at the margin of the bone defect (Fig. 4). This step may help to fill the cavity and increase the vascularity of the area. The tissue of the brow and bridge of the nose is then dissected carefully down to any bone that is beneath. If it is

absent this cannot be accomplished and individual judgment must be employed as to the extent to which the dissection is carried. The bleeding points must be completely controlled. The area is then ready for the reception of the graft.

INSERT MATERIALS

In the past, silver, gold, ivory, steel and celluloid have been employed with varying degrees of success. On the whole, they have been unsatisfactory because they have caused some degree of foreign body reaction in the tissues. The foreign body reaction as we know it, is an attempt to remove the material which is incompatible. The ideal material for replacing lost bone in the skull would be living bone. If this cannot be employed the next best material would be one that first, would be completely inert in the living tissues, second, would be no heavier than the bone removed, third, could be thick enough to obliterate all dead space, fourth, could be altered at operation, fifth, would be firm and sixth, could readily be made in any hospital laboratory. We now have at our disposal 5 substances which are on the whole well tolerated in this area. They are bone, cartilage, tantalum, vitallium and plastics.

Bone. Bone, of course, answers most of the criteria for an insert material. It can be obtained in sufficient quantities from the patient involved to replace that lost in the removal of the frontal bone. It forms a good firm protective coating and when in contact with the undisturbed bone forms a living union and tends to retain the characteristics it had prior to transplantation. Roentgenograms of these grafts will show evidence of decalcification in many of them and yet it does not indicate that they have not taken well. It may not be possible to restore the lost bone at one operation if the area is extensive but by successive grafts the goal may be reached. The donor areas for this purpose are fundamentally two in number, the front of the tibia and the crest of the ilium, though other operators might prefer different sites.

Bone taken from the front face of the tibia includes the entire width of the bone which may be 3 to 5 centimeters. It can be as long as is required which may be up to 12 or

centimeters in length. The thickness of this transplant depends upon the thickness of the cortex of the tibia but can usually be made from $3/16$ to $1/4$ of an inch thick. This broad flat smooth bone can be bent by grooving its under surface with saw cuts and its margin can be curved with either rongeurs or a saw. When such a strip is placed in contact with the fresh ened margins of the bony defect and held in place by the overlying scalp and a pressure bandage it has a very good probability of living.

It has been our experience that this tibial graft offers results more pleasing than other grafts. It creates a firm resistant protective covering comparatively free from irregularities.

Bone taken from the anterior portion of the ilium is somewhat more difficult to obtain in a long broad flat piece though in certain cases this is possible. It is easy to obtain in thin narrow strips and may be placed over the dura by overlapping the strips as one would shingles being sure that their ends are in contact with the margins of the frontal defect. Bone inserted in this manner has taken well and given excellent protection but is prone to result in an irregularity of the overlying skin (Fig. 5).

Cartilage. Cartilage also approaches the ideal insert material. It does not set up a foreign body reaction as it is a living material it can be built up to minimize dead space and can be altered at operation. Cartilage may be obtained in sufficient quantities from the costochondral margins of the host to fill in most of the cranial defects that we see. Being a comparatively inert living substance gaining its nutriment by diffusion it is an easy material to graft and usually takes very well.

It does however have drawbacks. It cannot be obtained in strips long enough to extend from one end of the defect to the other. If it could be so secured it would be unsatisfactory as it has a tendency to curl. This would not only create an irregularity of the overlying skin but might create undesired pressure inward.

Cartilage has been employed in the form of small chips (11). Utilized in this form it is jammed into the defect smoothed out and



Fig. 5. Patient in whom several strips of iliac bone were utilized for the repair of a large defect of the frontal bone. Postoperative recovery was good but there resulted an irregularity of the contour of the forehead, one of the most pronounced types of irregularity in the series we observed. In such cases it is often necessary to re-expose the bone months later and trim the irregular surface with a fine osteotome.

then the skin is permitted to hold it in place. In this manner it is apparently satisfactory for small defects but would not give the protective covering that is desired for large areas of exposed dura. Cartilage does not form an integral part as will bone and is therefore best suited for creating a contour of the brow on top of a bony transplant. For such a use it adapts itself well.

Metals as inserts. Metals have been utilized by surgeons since the 17th century for the filling in of bone defects. In 1665 Ictronius (22) employed gold for the repair of a cleft palate. The first use of metals to be applied to fractured bones was in 1775 when Lapexode and Siere (22) wound metal wire around a fracture. A little later in 1806 Rogers (22) of New York used silver wire in fractures. From that time forward various metals were advocated and used in all branches of surgery. The drawback of all these metals was that they either set up a galvanic current when in contact with the body fluids or there occurred a slow process of oxidation about them. For the past century therefore various workers have sought to secure a metal or an alloy that was nonelectrolytic and that was inert in the body fluid. Since 1900 there have been many experiments along this line and it was definitely shown that electrolysis of the metals was the



Fig. 6a.



Fig. 6b.



Fig. 6c.



Fig. 6d.

Fig. 6. Case. The entire frontal bone is missing. Flaps in place show marked depression and irregularity of the forehead. Note that the eyebrows are good as the incision is above them and not through them.

Fig. 8. Case. Postoperative result following insertion of solid thick vitallium plate, which obliterates any dead space. Note the smooth contour in both profile and front view.

disturbing factor when they were used in relation to the living tissues, and at body temperature (5-21). It was also found that the extent of the tissue reaction and damage was roughly equal to the galvanic action of the metals. Thus galvanic action is particularly marked when two dissimilar metals are employed in an alloy. When experimenting along these lines, the dental alloy vitallium was utilized and found to be quite inert, which was

somewhat surprising because it is an alloy. It was first used clinically in the form of bone screws by Venable and Stuck in 1936. Investigation of metals is still being conducted and there may be new alloys that will have advantages over vitallium.

Vitallium. Vitallium is an alloy of cobalt, chromium and molybdenum. It is hard, brittle and nonmalleable. If thin it can be bent slightly but it is too hard to cut or file with ordinary hand tools. Whenever we wish to employ this metal, it must be cast into the exact form to be used as very little changing of its shape can be conducted at the time of the operation.

To create a vitallium plate a model as nearly exact as possible must be made. If an impression can be made of the defect left at the time of the removal of the osteomyelitic bone it will be an exact fit. The only alteration that might occur in such a bed which would alter the fitting when we wish to insert a plate would be the ingrowth of bone from its margins, and this can be taken into consideration in making the plate. The next stage at which a model may be made is when the flaps have to be elevated, freed, and approximated. At this time the bony defect will have its final shape and an impression made then would not have to be altered. It usually becomes necessary to estimate the shape of



Fig. 7. Case. Solid vitallium plate with flanges, in place.

the model by constructing it over a cast of the healed wound. When this is done it is necessary to allow for the thickness of the skin. However a good approximation can be obtained so that when thin flanges are attached to the outer surface at the periphery they may be bent slightly at the time of the operation to compensate for variations in contour. The prepared model is then sent to a laboratory with facilities to reproduce it in cast vitallium. It is advisable to have perforations through the thin areas of plate to permit interchange of fluids and ingrowth of tissues.

To insert the plate the bed is prepared as previously described. The plate is then fitted into the defect by bending the flanges to correspond to the contour of the skull. Two or three screws are next inserted to immobilize it and the flaps reapproximated.

Vitallium is also made in prepared flat strips of varying lengths. They measure approximately 1 millimeter thick by $\frac{3}{8}$ of an inch wide by 2, 3 or 4 inches long. Each strip has holes in the four corners to permit fastening it to the skull. In selected cases these strips may be used to advantage and will be discussed later.

Tantalum. In recent years there has been produced the element tantalum in sufficient quantities to permit its use in surgery. Tantalum is practically inert not only in the laboratory but buried in the living tissues (1, 2, 6, 9, 18, 19). It is the 73rd element in the periodic table. It is strong, tough, malleable, and can be drawn and machined. It is soft enough so that it may be cut, filed and sawed with hand tools. It is however difficult to drill except with a slow drill as it apparently crystallizes by the heat of drilling, becoming very tough. By use of a punch, this difficulty is readily overcome. A formed plate of tantalum may be made by placing a sheet of the metal over a negative cast of the model (4). Over this is placed a rubber pad and by exerting pressure on this the metal flows into the desired shape. It may then be trimmed and perforated by hand tools. At operation further shaping may be carried out. Additional flanges may be cut where necessary and the edges trimmed. If a method of creating sufficient pressure is not available the plate may

be formed by hammering the tantalum sheet as one would hammer sheet silver or copper to fashion trays or the like. Once approximately formed the plate may then be inserted to replace the lost bone. The ease with which tantalum may be altered at the time of operation makes it possible for the operator to adjust the plate to a more exact fit than can be done with vitallium.

Tantalum cannot be cast as yet and is too soft a material with which to make screws so that it becomes necessary to use vitallium screws or a suture to hold these plates in place. The probability is that there will be a negligible electrolytic process set up between them and no reaction around the screws should result as both metals are nonactive.

Plastics. Under the term plastics are grouped substances which may be molded. This of course encompasses a large variety of materials. Those with which we are concerned are grouped under the acrylics, the basic one being methylmethacrylate. One form of this is known as plexiglass, another one lucite, depending upon the company which produces the material. It has been found that this material is well tolerated in living tissues (7, 20). It is firm, strong, can be cast and after heating can have its shape altered. It can be filed and drilled with hand tools. Theoretically it has the advantages of the metal plates plus the fact that it is not radiopaque so that an x-ray may be taken through it to determine the condition of the underlying structures. It has an added asset in that it is comparatively light and a thick cast will be lighter than the bone it replaces. Plates of this material can be made by anyone familiar with the formation of dental plates. All that is necessary is to have an exact model of the desired plate.

OBSERVATIONS FROM STUDY OF 38 CASES

When we are presented with a lost brow or a small defective area in the skull which is not more than 2 or 2½ inches in diameter it has been found that the utilization of a bone transplant is most acceptable. When the dura is covered with bone and it is merely the brow that has been lost, either bone or cartilage may be employed. It seems more advisable



Fig. 9. Case 2. Preoperative defect in patient. Ith fracture frontal bone and supraorbital ridges removed. Flaps not sutured. There is retraction and curling of the flaps and thin epithelial coating over the dura.



Fig. 10. Case 2. Postoperative result following the use of a perforated vitalium plate. Note that the contour is good and that there is but slight distortion of the brows.

to use bone to replace lost bone, even in this situation and it has proved to be best in our hands.

If a case presents a defect larger than $2\frac{1}{2}$ or 3 inches, it may be advisable to employ one of the materials that we now have at our disposal. When a preformed plate is used the operating time is reduced tremendously as is the operative shock to the patient. Thus improvement is made possible by the elimination of one entire operation—that of obtaining the bone or cartilage graft.

In each of the cases in which one-half of the frontal bone had been removed a bone graft was employed to fill in the defect. The support in each case was satisfactory and the cosmetic result though not perfect in all cases, was greatly improved. In the majority of cases in which bone grafting was employed there was some resulting irregularity of the skin overlying the graft, and this was more pronounced when iliac bone was used. This irregularity was largely obviated by the use of the smooth plates.

There were other cases in which the entire frontal bone had been removed. In some of these, it was possible to cover the defect satisfactorily with but one bony transplant. In others, it was necessary to employ 2 or 3 successive transplants. In addition to this, in 3 cases a dermal graft was inserted over the bone insert to smooth out irregularities and further raise the brow. It was found that this

improved the appearance remarkably for some months to a year but that the fat had a tendency to be absorbed so the original improvement was somewhat reduced. There was no evidence of cyst formation due to the burned basal layer of the skin.

Not infrequently the bone of the tibia may be quite brittle. This is particularly true in adults. In this state it is prone to fragment when it is removed by means of an osteotome. This may be overcome by utilizing a circular saw. Should it fragment the periosteum will hold the majority of the fragments together so that the main transplant may be carried out as though the desired strip had been obtained.

Following the transplant it is imperative to look for a collection of serum or blood about the graft, and if this occurs it must be evacuated immediately. Such a collection can occur in spite of drainage and a proper pressure bandage. Infection is always a potential cause of failure in these postoperative osteomyelitic cases for three main reasons: first there is nothing but fibrous tissue separating the nose from the operative field, and this tissue can be readily invaded by organisms from the nose; second, a small cystic mass is occasionally encountered in the scarred tissues which may contain dormant bacteria; and third the tissues with which we are dealing are quite scarred and their resistance to infection is reduced. Infection occurred prior to

the advent of sulfonamides more commonly than it does now

Infrequently a fragment of a graft will become infected. When this occurs it must be removed and once removed the inflammatory process subsides immediately. Rarely does the entire graft have to be removed, though this did occur in 2 of the cases. In each instance this arose in a case in which the plastic repair was conducted too soon after the active osteomyelitic process had supposedly ceased.

In 1 of our cases a tremendous hematoma developed in spite of the routine pressure bandage and drains. The day following the graft, the patient was reanesthetized the flaps opened up, the graft removed and washed, all clots were removed, minute bleeding points were controlled and the graft was reinserted. Following this second procedure there was no more reaction than is obtained with the average grafting case and the ultimate result was excellent (Case 3 Fig 14).

Cartilage was not used in any of our cases as a primary covering to the dura and has been used only in an occasional case for the creating of cosmetic contour.

To prevent edema of the soft tissues it is imperative to have a pressure bandage applied well over the top of the head. If such a bandage is not used a congestive edema of the scalp will appear in the unbanded area which reduces the circulation to the grafted area.

Prepared vitallium strips have a curve that would correspond to that of the contour of the average skull and are designed to be used as skull plates. In covering small defects these plates are easy to insert and serve this purpose well. We have employed them as such and have found that if they can be inserted so that their ends are in direct contact with the skull and that their edges conform exactly to the contour of the skull they will be retained and serve their purpose. This is particularly true when comparatively small defects are encountered but when the entire frontal bone has been removed and the shape of the defect is variable and not that of a sphere it is nearly impossible to bend these strips at the time of operation to meet the above requirements. Because of this diffi-

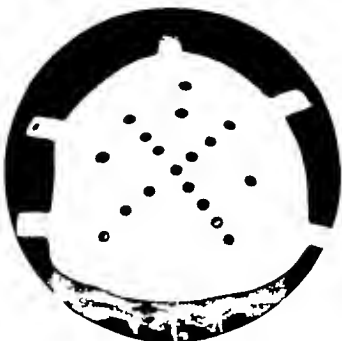


Fig. 11 Case 2. X-ray film of the preformed perforated vitallium plate in place

culty several of our strips have had an edge slightly above the normal contour. This has eroded through the scalp due to pressure atrophy and have had to be removed (Case 4 Fig 15). In 1 of these it was possible to remove the strip, cut off the area that had presented itself and reinsert the strip which then remained in place. In 2 instances it was necessary to remove one or more of the strips. The vitallium plates that are preconstructed obviate this difficulty and have been retained satisfactorily.

If we desire a thin plate to fill in a defect in the frontal bone, tantalum will probably prove to be the metal of choice for the following reasons. Experimentally it is the most inert of the two main metals at our disposal (5) and it is the more readily formed and altered of the two.

Soon after the insertion of either the strips or the plates, there is apt to be a generalized swelling which apparently occurs adjacent to the metal. Associated with this there is the customary swelling in the flaps themselves which gradually disappears within 1 to 2 weeks. This early swelling may subside and then reoccur 2 or 3 months later. In 1 case such swelling occurred about a year later and was due to a collection of fluid adjacent to the plate plus a fibrosis of the tissues over it. On



Fig. 2. Case 1. The presenting deformity. The patient is a 16-year-old female. Frontal sinus, plus removal of one-half of the frontal bone has been carried out. The patient is not interested in plastic surgery. The defect has covered the eyeball and that has invaded from the orbit.

excisions, it became necessary to prepare this fluid which was sterile, slightly turbid and yellow. In other cases it has ulcerated without any treatment and there has been practically no healing or tissue reaction during these episodes. We have found it advisable to have the flat plates perforated so that there may be a free exchange of fluid through from

the scalp to the space which I always present between the plate and the dura. Through these perforations there is also an opportunity for fibroblasts to grow into the space mentioned. This growth may eventually fill and obliterate the area. When the plate is thick so that its inner surface conforms to the shape of the dura and its outer surface to the shape of the facial bed I believe this dead space is avoided but the plate is necessarily heavy if made of vitallium.

In children there is some amount of bone regeneration that does not occur in adults so that this must be taken into consideration. We have no way of predetermining the regeneration or the amount of anticipated skull enlargement. It seems advisable therefore to use a live material such as bone when repairing the defects in children.

We have experienced bone regeneration in 2 of our cases and both of these were in children. There has been no x-ray evidence of regeneration in the adult. This confirms the observation made in skull trephines.

Plates have several practical as well as theoretical drawbacks. In the first place we are employing a nonviable material burying it within the tissues. Theoretically these may be well retained but practically we must await the test of time before we can evaluate their ultimate use. There have been cases in which gold and ivory have been well tolerated by the tissues for some years but



Fig. 3. Case 1. X-ray film reveals bony defect of one entire side of the frontal bone including the supraorbital rim and the temporal protuberance.



Fig. 4. Case 1. The end result following bone transplantation. The first from the iliac I cover the entire defect, the second from the iliac I raise the brow. There is still some irregularity of the forehead with slight deviation of the brow.

eventually had to be removed because of sepsis or reaction about it. When we wish to insert a plate it must be prepared to fit the defect as accurately as possible prior to the operation. This is particularly true of vitallium and the acrylic plates which must be precast from a model. It is nearly impossible to alter the shape of a vitallium plate at the time of operation. The only alteration possible is that of the flanges about the periphery. When a flat plate is employed for covering a bony defect there is left between it and the dura a void space which is a potential source of trouble. This dead space has not caused trouble in our cases other than the accumulation of fluid but should the fluid become infected it might be difficult to clear without removing the plate.

To date we have used tantalum and acrylics in but 1 case each. The individual receiving the tantalum was originally operated upon by a surgeon who employed an inverted U incision that was closed early. Following the insertion of the plate there was very little local reaction. This plate was well perforated.

The patient receiving the acrylic plate has but recently been operated upon so that only the immediate reaction can be noted and that was good. If this material is as well tolerated as we hope it will be it will probably play an important part in the replacement of lost cranial bone.



Fig. 16. Case 4. X-ray film showing the plates in place having been bent to conform to the skull contour.

SUMMARY AND CONCLUSIONS

The plastic repair of 38 cases of post operative osteomyelitis of the frontal bone has been reviewed. The indications for operation, the choice of implant material and the complications encountered have been considered.

Bone cartilage vitallium tantalum and an acrylic have been employed to replace lost frontal bone. The viable transplants should be employed when practical as there is no perfect substitute for living tissues. Cartilage may be utilized for replacing small areas of lost bone or for improving the contour of the brow over a previous bone graft. Bone should be used to fill in defects up to 2½ inches in diameter. It is advisable to employ bone in children as there is some regeneration in these cases as well as a change in skull size. In larger areas it is much easier and the cosmetic result on the whole is more satisfactory when one of the prepared plates is inserted.

If the plates prove to be perfectly tolerated they will in time replace the living transplant as they offer the best protection to the brain and materially reduce the problems encountered in transplant operations.

Of the plates that may be considered vitallium and the acrylics must be precast from models and there is but slight alteration that



Fig. 15. Case 4. Photograph which illustrates the erosion of a vitallium strip through the brow due to its being elevated slightly above the bone. Note that there is no evidence of infection or inflammatory reaction about the vitallium strip.



Fig. 7



Fig. 8

Fig. 7. Case 5. Defect in which entire frontal bone is missing. The forehead flaps have retracted and the dura has been covered with epithelium.

Fig. 8. Case 5. End-result following the bone grafts.

may be made at the operating table. Vitallium must be cast by a special laboratory technique. The model given to the laboratory must therefore be exact. Acrylics may be cast by anyone familiar with the technique and the shape may be altered at operation by heating the plate. Both of these materials have the advantage of creating a plate that can fill in the thickness of the lost bone which it is to replace as well as offering a smooth external contour. A cast in vitallium has the disadvantage of being quite heavy while one of acrylics is light. A plate of tantalum must also be preformed but it may be altered by hammering and cutting at the time of operation. It has the disadvantage of leaving a dead space between it and the dura which is a potential source of trouble. We may assume that the bone and cartilage grafts will be tolerated indefinitely as they have previously been well tested. The inert inserts must be subjected to the test of time before judgment may be passed as to their ultimate fate.

CASE 1. M. J. F. a 15 year old boy was operated upon for osteomyelitis of the frontal bone following swimming. The entire frontal bone was removed through an inverted T incision. The flaps and the wound were left wide open. Sulfathiazole was blown into the area, and 3 weeks later the flaps were brought together and sutured in place. Three months later the boy developed cold. He had pus in his nose, and the wound just above the eyes opened and drained pus. Two months later a left



Fig. 9

the first from the front face of the tibia, the second, taken from the crest of the ilium to improve the contour of the brow.

Fig. 9. Case 5. Preoperative defect of frontal bone.

external ethmoidectomy was performed, as this was the site of his recurrent infection. Four months later he was admitted to the plastic service for the insertion of a prepared vitallium plate. He presented a fairly smooth scalp but very flat due to the absence of frontal bone, including the supraorbital rim, and the entire area was pulsating (Fig. 6).

Under general anesthesia, the skin of the forehead was removed from the dura and elevated from the normal bone. The periosteum was incised about the periphery of the defect, was elevated, brought medially and sutured to the dura. A prepared vitallium plate was inserted and the flanges were bent to conform to the contour of the skull (Fig. 7). Three holes were drilled in the bone, corresponding to three of the holes in these flanges, and vitallium screws were inserted to hold the plate in place. This plate was solid and thick, thus obliterating any dead space. The overlying skin was then reapproximated and sutured with interrupted atraumatic sutures. No drains were inserted. The patient recovered uneventfully and the result was gratifying (Fig. 8).

CASE 2. P. F. M. male, age 30 years, had an operation a year prior to admission for subacute osteomyelitis of the frontal bone following swimming. At operation the entire frontal bone was removed, but the supraorbital ridges and floors of both frontals were saved. His convalescence was uneventful.

On admission to the plastic service, he presented the large inverted T-shaped scar on the forehead extending posteriorly to the parietal region of the sagittal suture. The skin flaps were separated and retracted laterally. The region of the frontal bone was flat (Fig. 9).

Operation consisted of "plastic repair of the frontal bone and insertion of prepared vitallium plate." Convalescence was uneventful though there



Fig. 20.

Fig. 21

Fig. 20. Case 6. Preoperative defect in which the entire frontal bone was removed and part of the cereb. r. lost.

Fig. 21. Case 6. Contour following repeated bone grafts utilizing bone from the ilium, plus vitalium strips which were placed on top of these. One of the strips near the supraorbital ridge eroded and had to be removed.

was some postoperative swelling which gradually subsided.

A month later he had a marked swelling of the forehead which was not fluctuant or tender. The tissues were thickened and indurated. This gradually subsided without intervention (Figs. 10 and 11).

CASE 3. L. H. aged 25 years had an acute sinusitis following swimming and developed an orbital abscess. A Lynch frontal and anterior ethmoid operation was done, and the convalescence was uneventful. A month later the swelling of the forehead had not completely subsided and he had a generalized convulsion. At this stage he was admitted to the Massachusetts Eye and Ear Infirmary where it was evident that he had an osteomyelitis of the frontal bone extending out of the left frontal sinus.

At operation the bone was removed. It was definitely discolored but no perforation was seen in it. The posterior wall and floor of the frontal sinus were removed and the wound was left open. The organism was *Staphylococcus aureus*. Four months later the patient was readmitted to the plastic service for a closure of the operative defect (Figs. 12 and 13). Under local infiltration, the skin flaps were dissected from the dura and the epithelium over the dura was removed. The periosteum was incised 1 inch beyond the margin of the defect and reflected medianward and sutured to the dura. A graft of bone was then taken from the tibia, shaped, and applied to the area of the bony defect. The skin flaps were then brought together and sutured in the midline, and small drains were placed in the incision. A pressure bandage was applied. The following day a huge hematoma had developed and the patient was vomiting. Under local infiltration the sutures were removed, the flaps laid back with ease, and a huge hematoma was revealed about 2 centimeters thick, overlying the graft and exposed dura. No



Fig. 22. Case 6. Preoperative bone defect.

bleeding points could be found. The grafts were removed, cleaned of clots, and washed in saline. The wound was cleaned, washed with saline, hydrogen peroxide, and finally a 1:1000 adrenalin solution was used to control the general oozing. The bone was then reinserted, the flaps brought together and sutured, and a pressure bandage, utilizing a rubber sponge, was employed. The convalescence following this was uneventful. The end-result from the operation was quite satisfactory but there remained a depression above the left eyebrow so that a year following the original plastic operation, a further bone graft was inserted to fill out the contour of this region. This bone was taken from the ilium. X-ray films taken a few months later revealed complete closure of the bony defect, sinuses were clear, and on observation the forehead looked well (Fig. 14).

CASE 4. E. J. aged 11 years, 3 months before admission to the plastic service this young boy had an operation for the removal of osteomyelitis of the frontal bone, an obliteration of the left frontal sinus, and an ethmoidectomy. This operation was done through an inverted T incision. The dura was clean but was covered with sulfanilamide powder and the flaps were left open. The patient had a very stormy convalescence.

When the patient presented himself to the plastic service, it was observed that the area had healed well, that there was no evidence of infection, but that the customary scarred tissue over the dura was present, plus the corrugations of the flaps. The routine removal of the scarred tissue and freeing of the flaps was conducted and the bony bed pre-



Fig. 23.

Fig. 24.

Fig. 23. Case 7. Comparatively minor defect in which small area of the frontal bone was removed together with the supraorbital ridge.

Fig. 24. Case 7. End-result following an inset of graft taken from the cortex of the tibia.

pared as previously described. Three standard vitalium strips were placed over the frontal bone defect. Each one was bent so as to fit its specific area. This was very difficult to do as it would have been desirable to bend the flat strips in two planes, which was impossible so that at best the plates could not be brought in contact with the bone smoothly, and the long edges, though they were smooth, did not conform exactly to the contour of the removed bone. The skin flaps were sutured together and pressure bandage was applied. Following this operation, convalescence was uneventful, and the immediate result was satisfactory.

Five months later the corner of one of the vitalium strips was protruding through the skin (Fig. 5). This protrusion had apparently occurred by pressure necrosis as there was no inflammatory reaction about the plates as a whole. This plate was loosened, the protruding corner was cut off, and the strip further bent so that the edges could be pressing against the skull. The skin edges were then reapproximated (Fig. 6).

Six months later the condition of the patient was unchanged, but it was apparent that the long edge of the bottom plate had been gradually approaching the surface and was visible beneath the epidermis. In view of this process, all the plates were removed and an uneventful convalescence followed.

Two months later the patient had an attack of epilepsy but complete neurological examination revealed no evidence of a localized lesion, and the patient was discharged for observation.

When this patient's tissues have had time to reestablish their vascularity a plate of vitalium will be made and inserted.

Case 5. F. R. male, aged 3 years, had acute osteomyelitis of the frontal bone associated with acute bilateral, frontal and maxillary sinusitis 1 year before admission to the plastic service.



Fig. 5. Case 7. Preoperative defect. Merely the obliteration of the frontal sinus on one side and the removal of a small area of frontal bone.

At operation the frontals were obliterated and the frontal bone removed. One small area of the bone appeared to be diseased and contained pus. There were 3 areas of collected pus on the dura with some granulations around each one. These were about 1 to 2 centimeters in size. There was no further evidence of osteomyelitis according to the x-ray films, and clinically the patient recovered.

The patient presented the usual inverted T scarred area with retraction of the forehead flaps (Fig. 17 and 9). Under general anesthesia, the customary dissection and mobilization of the flaps was performed and the bone prepared to receive the graft. A cortical graft was taken from the tibia, shaped, and placed over the defect, completely covering the dura. The convalescence was uneventful, but in 3 months, further bone grafting was done to improve the contour of the forehead, particularly that of the brows. This time the bone was taken from the iliac crest. Convalescence from this operation was uneventful, and the end-result was unusually gratifying (Fig. 18).

Case 6. W. B., male aged 3 years, had a past swimming sinusitis, osteomyelitis, extracranial abscess and meningitis 8 months prior to admission to the plastic service. After a stormy course in which all of the frontal bone was removed, he presented himself with the flaps retracted, the dura covered with epithelium, and a very flat forehead (Fig. 20 and 19). At operation the retracted flaps were freed, the dura cleaned of epithelium, and the flaps approximated and sutured. The appearance of the forehead at this period was markedly concave. Six months later bone was taken from the ilium, shaped and inserted beneath the flaps. It was impossible to cover the entire forehead due to the tremendous area involved. The convalescence from this was un-

eventful. Four months later he developed marked pain and swelling over the glabella region. There was no history of recent infection or cold. An abscess developed which was incised and drained. It subsided without further trouble. Six months later he still had a small draining fistula at the roof of the nose. X-ray films showed no evidence of infection and that three fourths of the bony defect had been filled in by bone. Eighteen months following the first bone graft further transplantation was done and bone was taken from the iliac crest in the form of strips that were fitted into the defect, and held in place by the closed scalp. This improved the contour and shape of the forehead considerably but there was still much depression above the hairline, and there was still marked depression in the region of the brows. Four months elapsed when the flaps were again elevated and a small standard vitallium strip was placed over the brow just over the roof of the bone and sewed in place. Two more vitallium strips were placed above the first one and sewed in place the skin approximated and a pressure bandage applied. One month later the ends of the vitallium strip that were near the brow had eroded through the skin and had to be removed (Fig. 21).

CASE 7. W. E., aged 18 years, was operated upon for osteomyelitis of the frontal bone associated with a brain abscess 12 years ago. Since that time there have been no complicating symptoms. Examination showed a vertical L-shaped scar extending from the center of the forehead to the eyebrow. It was wide and adherent to the bone. The skin within the area of the L was puckered and elevated (Fig. 23). Palpation showed absence of bone beneath the area. The eyebrow was distorted. X-ray pictures of the skull and sinuses showed no evidence of infection but a bony defect measuring 1 by 3 centimeters in size (Fig. 25).

At operation the scar was excised and the flap dissected away from the dura to existing bone. The scar tissue over the frontal defect was thin and in one area a small cyst was encountered. The forehead was prepared for the reception of a bone graft

and a rectangular piece of bone 2 inches long and 1 inch wide was removed from the cortex of the tibia shaped and inserted over the dura with its periosteal side outermost. The skin flaps were then closed over the bone graft and a pressure dressing applied. The patient made an uneventful convalescence (Fig. 24).

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ALPHA RAYS IN THE TREATMENT OF WOUNDS

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THE therapeutic potentialities of radium and radioactive substances are not utilized to their fullest extent. Some of the principal reasons for the conservative attitude toward their use are the relative rarity of the element the inconveniences connected with the handling of radioactive substances, and the fact that many physicians are not familiar with the technical application of radium and its disintegration products. The use, therefore, of radioactive substances in medicine is generally limited to the treatment of malignant tumors. This important employment of radium, however does not exhaust its therapeutic usefulness, and developments in the past two decades have shown that other diseases may be treated successfully with radioactive substances. Furthermore, technical progress has made radium products more readily available, and in such form that they can be safely used by every physician.

In order to avoid loss of the valuable element, and for economic reasons, radium itself is often substituted by radium emanation, also called radon a disintegration product of radium in gaseous form. This substance has the same qualities as radium, but can be, and has been, used in forms in which radium itself cannot be prepared. A distinct feature is the fact that radon is readily absorbed in fluids such as water or alcohol, and is easily incorporated in fatty substances. This property not only facilitates its therapeutic application but also permits utilization of the alpha rays emanated by radon. It will be shown that α -radiation is of great therapeutic value in wound healing and the probability that war wounds may be benefited by its application prompts this publication.

Little use has been made of α -rays in medicine and only a minority of physicians is generally aware of the fact that over 90 per cent of all the emanation from radium and radon consists of alpha particles, the rest being β - and γ -rays. The pathway of α -rays is very limited, amounting to only a few centimeters in air of normal density and their penetrating power is so slight that the walls of the containers ordinarily used for radioactive substances absorb all the α -rays given off. These qualities nullify the usefulness of α -rays for the treatment of malignant tumors, in which, ex-

cept for lesions on the surface of the skin, the penetrating γ -rays have the chief therapeutic value. However when radon is incorporated in fluids, fats, these substances can easily be brought close contact with lesions on the surface of the body and full advantage can be taken of the α -rays.

As long as twenty years ago, Strasburger (1) introduced radon in a liquid vehicle into therapy. For the past 15 years (2) radon dissolved in fatty substances has been successfully used for the treatment of skin changes and ulcerations which resulted from overdosage of x-rays and radium. These ulcerations are characterized by the associated with their appearance, their reaction to therapy and by their eventual development into cancer with all its consequences. It is well known that many of the pioneers in radiology being in their time utterly unaware of the dangers of overexposure, succumbed to x ray cancer.

It may seem odd and inconsistent to attempt the cure of injuries produced by x rays or radium with the same agent, but it must be emphasized that the recommended therapeutic factor for these skin changes consists of α -rays which are corpuscular elements and physically different from γ -rays of radium or x-rays. In the dosage employed for these treatments, α -rays have been proved to be absolutely harmless in many thousands of applications.

Radon incorporated in neutral fat is a source of α -rays and has the appearance of an ointment. It can be handled like other salves but consideration must be given to the fact that it is not a stable product. Radon disintegrates and loses its strength by continuously giving up part of its charge. This loss has been exactly determined and amounts to about 16 per cent in every 24 hours. An ointment with a known amount of radon will lose half of its concentration in about 4 days. This quality necessitates the preparation of fresh material for therapeutic applications, and the exact determination of its concentration in order to evaluate the time element for its use.

The construction of suitable apparatus and measuring instruments has made the task of preparing radon ointment and determining the exact dosage comparatively simple, and the material has been made available to the medical profession for general use. The actual amount employed for

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the therapeutic purposes described here is exceedingly small. Radon in this form is measured in electrostatic units (e.s.u.) 1 electrostatic unit being equal to 0.000364 millicurie destroyed (m.c.d.) Since familiarity with these physical standards cannot be generally assumed it may suffice to mention that 10 cubic centimeters of radon ointment containing a total of 1000 electrostatic units (100 e.s.u. per c.c.) can be applied continuously for more than 100 hours before an erythematous reaction of the skin will be produced.

Another factor important for the therapeutic use of radon ointment must be mentioned. Radon as previously stated is a gas and has the tendency to escape. To prevent this, the ointment is prepared and shipped in sealed tubes or in tin containers, and when used for therapeutic purposes, should be applied under dressings as airtight as possible. In the treatment of surface wounds, this can be easily accomplished by spreading the ointment over the lesion covering the area with rubber dam, cellophane, oilcloth or similar material and finally sealing the dressing with adhesive tape in overlapping strips. These dressings must be applied by the physician and are left in place for an exact and predetermined time. They then can be removed by the patient. Repetition of the treatment is usually done at intervals of 3 to 7 days. The treatment time depends upon the nature of the lesion, and the number of treatments required is influenced by its size.

The use of radon ointment was originally limited by the author to the treatment of wounds which had proved to be resistant to all other forms of therapy and in cases in which wide excision of tissue with subsequent grafting of skin or even amputation of limbs was contemplated. Most of these lesions were sequelae of overdosage



Fig. 1. Case 1. a, left, Before and, b, after 5 weeks of radon ointment treatment.

of x rays or radium. The results obtained were extremely gratifying. Consequently when radon in this form became more easily obtainable other skin conditions with similar resistance to ordinary therapy were subjected to these treatments. Periodic histological studies of such lesions showed that new capillaries were formed under radon ointment therapy. Therefore these treatments were instituted in ulcerations of the skin where the local blood supply was incompetent. In this manner patients suffering from Buerger's disease, varicose ulcers, necrotic lesions including diabetic gangrene, resistant burns resulting from heat or electric current, and draining fistulas were successfully treated.

During the past year the influence of α -rays on experimental surgical wounds in rabbits' skin was



Fig. 2. Case 2. a, left, Before and, b, 6 months after radon ointment therapy.



Fig. 3. Case 3. a, left, One week after removal of carcinoma of hand and 3 1/2 weeks later after treatment.

studied and valuable information in the subject of wound healing and scar formation obtained. These wounds, as he reported in a separate communication, did not show any gross or histologic changes in human tissue but in the response to radon ointment therapy a surprising similarity in rabbit and human skin was observed. Uniformly the

healing process of extensive wounds was accelerated by the application of radon ointment.

Clinical results obtained in surgical wounds selected on the basis of experience gained in the experimental work confirmed the value of radon ointment application. The rate of wound healing was greatly hastened, and surprisingly soft scars were produced without impairment of function. Some of these histories are briefly presented:



Fig. 4. Case 4. a, left, After removal of epithelioma, and, b, after 4 treatments with radon ointment.

CASE II. S. (carcinoma of the skin below the left eye) treated with radium in 17 and 1935. Discharge known in 1940, an excision of the lesion performed but the lesion recurred, and another operation was carried out in 1941. There was granulation tissue in the wound, and on several occasions biopsy specimens were taken from this tissue. Each in some instances showed remnants of carcinoma. Initially the wound became clean and March, 1943, appeared (illustrated in Figure 1). The tissue defect measured about 3.5 centimeters by 3 centimeters, and 1 centimeter deep. The peritumors as exposed and bled there was no clinical evidence of carcinoma, the possibility of carcinoma of the bone was considered. Biopsy specimens taken from the margin of the lesion at that time did not show any microscopic evidence of carcinoma. Skin grafting was contemplated to cure the lesion. Before that as done treatments with radon ointment were begun on April 5, 1943. After applications, new granulation tissue formed along the edges and over the base of the lesion, and under continuous treatment the defect filled in. After 5 weeks the lesion presented the picture as shown in Figure 2, but applications of radon ointment were continued until July 5. Without much change in the appearance of the scar. A total of 10 treatments, each lasting over 8 hours, as applied, and the lesion has remained unchanged in follow-up period over 6 months. The scar is soft and shows no tenderness. After



Fig. 5. a, left, Wound after radical mastectomy. b Therapeutic result after radon ointment treatment.

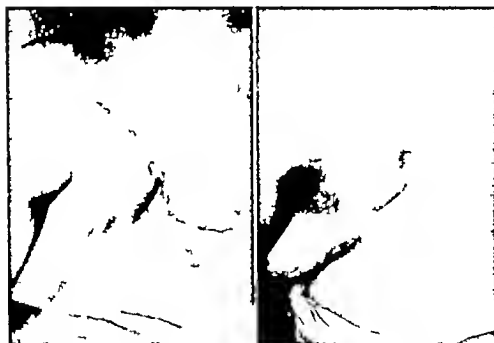


Fig. 6. a, left, Similar lesion to that in Figure 5. b, after treatment.

this paper was submitted for publication the patient developed an erosion the size of a small pea in the medial part of the scar with indurated and hyperkeratotic borders. Recurrence of the original carcinoma was suspected and biopsy advised.

CASE 2. F.Y. had an eczema of the left lower extremities and received more than 30 x-ray treatments in 1937. Following these treatments she developed severe reactions over the left heel and ankle which resulted in an ulceration of the skin which failed to heal. She was under constant medical care with all types of treatments including cautery, and during the year 1942 developed hard indurated areas in the

borders of the ulcer. The patient was first seen in the department on February 1, 1943, with the lesion as described, and biopsy tissue was taken from the margin of the ulcer. The section showed a squamous cell hyperplasia, suspicious of carcinoma. On February 9, she was operated upon, and the entire ulcerated area was removed. The surrounding tissue showed atrophic changes with telangiectases. The defect resulting from the operation measured 10 by 5 centimeters and had the appearance as in the Figure 2a. Radon ointment therapy was started on February 15 for an 8 hour period and repeated on February 18. Following these 2 treatments there was so much improvement with



Fig. 7. Case 7. a, left, Ulcer of leg before, and, b, after radon ointment therapy

formation of granulation tissue that the patient could be discharged from the hospital and returned to Alabama for continued radon ointment therapy as an ambulatory patient of her local physician. Subsequently 3 more radon treatments were given in the ensuing 3 months, and the patient returned for follow-up examination on August 5, 1945. The photograph taken at this time showed the appearance of the heel as in Figure 8b. Four more treatments of radon ointment were applied between August 3 and September 9, with further improvement of the scar.

CASE 3. Dr. H. L. The patient is a physician who had exposed his hands to x-rays over a period of 30 years with the production of severe trophic telangiectases, and hyperkeratosis on both hands. In 1940, a small tumor on the dorsum of the right hand started and grew into a mass measuring 4 by 5 centimeters protruding 2.5 centimeters above the level of the skin. This was typical x-ray carcinoma, the surrounding parts of the skin showing typical x-ray changes.

On September 7, 1945, the carcinoma was removed surgically down to the tendon sheaths, and radon ointment therapy was started on September 22. Figure 9a taken on September 24, 1 week after operation, already showed granulation tissue on the bottom of the lesion, and under continued therapy the lesion healed within 3½ weeks with

total of only 6 radon ointment applications. The resulting scar is unusually soft and does not in any way limit the movements of the hand. Figure 9b taken at follow-up examination at a later date, shows the therapeutic result. The patient was last seen in November 1945, and there was no change in the appearance of the hand.

CASE 4. D. G. The patient had an epithelioma on the left side of the nose for several years and received radium treatments some years ago. It was first seen in the department on July 26, 1945, and showed swelling of the left cheek and the left side of the nose with deep ulcerations and some areas of hypertrophic tissue. It was thought at that time that the patient had radiation injury and carcinoma, and following some treatments with radon ointment, most of the ulceration healed except for the central part which measured about 5 by 2 centimeters, and showed hard and elevated borders. This lesion had the typical appearance of carcinoma, and the entire area was removed surgically on September 3 (Fig. 10a). Macroscopic examination of the specimen confirmed the diagnosis. Treatments with radon ointment were started on September 27 and continued for 3½ weeks. Granulation tissue began to form immediately after the first application, and after four treatments (the last one given on October 14) the lesion was completely healed as in Figure 10b.



Fig. 8. Case 8. a, left, Before and, b, after the administration of radon ointment treatment of arteriooclerotic

ulcers on the toe of the right foot and over the right metatarsal joint.

These 4 cases are presented to show the effect of radon ointment therapy on the healing of surgical wounds. In all cases, operations were performed for the elimination of carcinomas in an area previously injured by radiation. It is well known that under these circumstances the wound healing is not very satisfactory due to the lack of circulation and atrophy in the surrounding tissue. We have frequently observed patients with similar lesions in which following the surgical removal of the neoplasm skin grafts were carried out and failed to take. In the cases just mentioned the surgeon who performed the operations was very skeptical about the outcome, and based this skepticism on his experience in similar instances. But all these patients could be discharged from the hospital within 1 or 2 days except in Case 2 in which for reasons of convenience, the patient stayed 9 days in the hospital before the treatment was continued ambulatorily. The rate of wound healing was unusually fast and the resulting scars impressed us with their soft, smooth nonadhering appearance.

In connection with this description mention should be made of similar experiences with radon ointment therapy in a related field. Following extensive operations, as for example, radical mastectomy in cancer of the breast, the wound healing is often slow and sometimes requires many weeks or even months before drainage from the scars stops, and complete healing takes place.

Figure 5a shows a wound following a radical mastectomy in a patient who had a local breast operation several months before the radical mastectomy was performed. The mastectomy therefore, was done under a handicap on April 17, 1943, and on May 30, the wound showed the appearance as illustrated. There was no progress in wound healing for the ensuing 3 weeks, and the patient complained about severe pain and drainage. The actual wound measured about 10 centimeters with an average width of 4 centimeters and a depth of 1 centimeter. Radon ointment therapy was started on May 29, and continued until June 31, 3 treatments being given. Following the second application, the wound was less than one-half its original size and was completely healed by the end of June, 1943. Figure 5b shows the therapeutic result following the application of radon ointment.

Figure 6a shows a similar pathologic lesion in which a radical mastectomy for carcinoma of the breast was performed on June 15, 1943. The center of the wound did not show any tendency of healing, and presented a necrotic ulceration measuring 1.5 by 2 centimeters. Radon ointment therapy was started on July 19, and 6 more applications were given to the area. Figure 6b shows the appearance of the lesion on September 2, 1943, again indicating the soft, nonadhering scar following radon ointment therapy.

These are only 2 examples of a number of patients with nonhealing operative scars following various types of operations. In some instances,

there was drainage of wounds from abdominal operations from 6 to 9 months, and 3 or 4 applications of radon ointment were sufficient to produce a soft scar and the cessation of drainage.

The following description is an example of a lesion in which no surgical excision was carried out but in which other surgical procedures were unsuccessful.

CASE 7. H. G. The patient had a varicose ulcer on the left lower leg for over 4 years. Many types of therapy were carried out during this time without appreciable improvement. Within the past year skin grafts were performed by various competent surgeons on three different occasions, but these did not take, and the patient was eventually referred for radon ointment therapy. Figure 7a shows the large ulcer measuring over 4 centimeters in diameter on the left lower leg and according to the patient, there had been no change in the appearance of the lesion for the past 6 months. Radon ointment therapy was started on October 14, 1943, and 3 weeks later the lesion was about one-half its original size. Treatment was continued until November 29, 1943 and Figure 7b shows the result obtained within this time.

Finally successful therapy with radon ointment is reported in a case in which radical surgical procedure could be avoided the patient suffering from diabetes for many years.

CASE 8. M. R. When first seen in November 1939, the patient had been in the hospital for the treatment of two arteriosclerotic ulcers on the toe of the right foot and over the right metatarsal joint. After 3 months of conservative treatment, the lesion showed the appearance as illustrated in Figure 8a, and since no further improvement could be achieved, amputation of the leg was contemplated. There was faint pulsation in the anterior and posterior tibial arteries. Radon ointment therapy was started on November 1, and continued for 6 weeks until December 13, 3 treatments of 8 hours each being given altogether. Following these treatments, the lesions were completely healed and showed the appearance as illustrated in Figure 8b. The patient has remained under our control, and the ulcers have remained cured now for over 4 years.

The photographs of the patient last mentioned taken before and after radon ointment therapy show better than any lengthy description the results obtained with this new form of therapy. However they do not fully demonstrate the type of scars which were obtained in healing these lesions. These were surprisingly soft and appeared to be epithelium rather than scar tissue. Surgical wounds in areas of impaired nutrition without spontaneous tendency of healing or operative wounds which failed to heal for several weeks or months were greatly benefited by radon ointment applications as were several varicose ulcers of long standing and diabetic gangrene which had been treated unsuccessfully by other methods. In some instances, skin grafts had been performed at a previous date without beneficial results (Case 7), and in others, as in Cases 2 and 3 skin grafting had

been contemplated and was not carried out because the prompt response to α -ray therapy made this procedure unnecessary. In other instances not mentioned here similar results could be obtained in skin burns of second and third degree resulting from heat and electric current.

SUMMARY

The use of α -rays in the treatment of wounds has been very successful. Some of their values lie in the fact that

1. They can be used in ulcerations in which the local blood supply is impaired and which do not respond to other forms of therapy

2. The treatments can be carried out easily by every physician who has familiarized himself with the method and the patient can usually be cured for in an ambulatory manner

3. The wound healing process is greatly accelerated.

4. The resulting scars are extremely soft smooth, nonadherent, and do not impair the function of limbs even if present at joints.

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A NEW SIMPLIFIED METHOD OF DEFUNCTIONALIZING THE COLON

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THE progress of large bowel surgery has been retarded for many years because of the omnipresence of pathogenic organisms residing there. Reconstructive procedures on the colon and rectum have been attended by a high morbidity and mortality.

There are two dominant reasons why the pathogenicity of organisms in the colon influence the ultimate result of operative procedures on this portion of the gastrointestinal tract. First in an open procedure when a portion of the colon is resected and an anastomosis done, there is usually some contamination of the operative field from the contents of the bowel, regardless of the meticulous care of the operator. If the peritoneum cannot resist the invasion of these organisms, there is a predisposition to postoperative peritonitis, intra-abdominal abscess, fecal fistulas, or wound infection. Second even in the so called aseptic anastomoses when colonic organisms are present in high concentration the suture lines do not heal under ideal conditions and leakage may occur.

For the past few decades, surgeons have tried to render the colon relatively aseptic by various means. The different cathartics were tried with poor results. Enemas of the various antiseptic solutions and solutions of low surface tension were proved ineffective. Enemas and instillations of drugs were tried by way of colostomy to no avail. In the latter method when a simple cecostomy or loop colostomy was performed the cleansing of the distal colon was impossible because of the overflow of septic feces from a point proximal to the artificial opening in the bowel to that distal.

In 1938 Sir Hugh Devine overcame this obstacle in his published report on the defunctionalized colon. According to Devine a defunctionalized colon is one which has been completely disconnected from the alimentary canal so that it cannot be soiled in any way by even the smallest quantity of the feces, one from which the fecal contents have been washed out and one which has been allowed to remain functionless until such time as the bacterial content has been considerably reduced reduced on the principle that if

experimentally a segment of bowel be completely isolated and thus deprived of its function it will lose most of its bacterial content. Devine points out. The two important points in this method of operating on the defunctionalized colon are, first, that the operation is carried out under favorable conditions, that is absence of septic feces, functionless contracted colonic walls and low bacterial count and second that the wound in the intestine is allowed to heal under these conditions.

Devine defunctionalized the distal colon in a two stage procedure. A loop of bowel (which must be a mobile loop usually a portion of the transverse colon) is brought up clamped and bisected with the cautery and a spur is formed by uniting the two segments of colon by suture. Two small incisions are made in the skin on either side of the initial incision, the ends of the bowel are then brought up under the skin and onto the abdomen through the two incisions previously mentioned thus the proximal and distal portions of the colon are separated by an expanse of skin preventing the spillage of feces from the proximal into the distal segment. In the next stage, after the lesion has been excised from the distal loop the spur must be crushed and in the final stage the stumps of bowel must be turned in and the wound closed.

There are many faults with the Devine colostomy. It can be performed only on a mobile loop of colon with any facility usually the transverse colon and is obviously inadequate for operative procedures in this portion of bowel or proximal to it. It is a two stage procedure which necessitates more than one anesthetic with its concomitant dangers. It is a fairly lengthy first stage operation, in view of the fact that it is only an adjunct to the main procedure. There is more than one skin incision which is undermined when the loops of bowel are brought out, with an increased chance of infection. There is also the factor that the bisection of the bowel when the loops are being formed introduces the possibility of contaminating the peritoneal cavity in the first stage.

In the new simplified method of defunctionalization to be described all of Devine's pre-

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Fig. 1. Original tube. A, Inflated balloon. B, proximal opening of main lumen. C, tube for balloon inflation.

requisites are met, without completely disconnecting the alimentary canal. It may be used to decontaminate any part of the large bowel distal to the first portion of the ascending colon. It is simple and entails only the use of a temporary cecostomy or loop colostomy. These procedures are done routinely preliminary to large bowel resection, especially in the presence of obstruction.

The procedure is as follows. A temporary cecostomy or colostomy is done. After 4 or 5 days, when the bowel is firmly peritonealized, a special tube is inserted distally through the opening in the colon. This tube is essentially a double lumened enema tube with an inflatable balloon attached (in the manner of a Miller Abbott tube, Fig. 1). The main lumen is through and through with a diameter of three-eighths of an inch. The smaller lumen is the means by which the balloon is inflated. At first, this home-made tube was used, but due to certain difficulties which will be described later a Bardex barium enema tube was found much more suitable (Fig. 2). The tube is greased and inserted into the colostomy proximal to the lesion. The balloon is inflated with the amount of air necessary to fill and distend this portion of colon (Fig. 3). Thus, the balloon obstructs the passage of contaminated feces from the portion of the bowel proximal to the balloon to that distal. The feces exit through the line of least resistance, the colostomy opening (Fig. 3 insert). The main lumen of the tube, however, is open and connects with the outside the segment of bowel to be defunctionalized. Cleansing irrigations may be administered through this lumen and siphoned off thus decontaminating the segment of bowel with the lesion. In this manner any portion of the colon distal to the first portion of the ascending colon can be readily defunctionalized. The only complications would be those inherent in the simple colostomy.

Relative to its surgical use, this method of defunctionalization is especially adapted to open

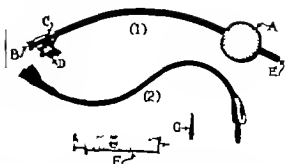


Fig. 2. Bardex No. 30 barium enema tube for ascending and transverse colon. A, Inflated balloon (50 cubic centimeter capacity). B, proximal opening of main lumen. C, opening for balloon inflation. D, Hoffman clamp. E, distal opening of main lumen. F, 50 cubic centimeter syringe (for accurate measurement of inflation). G, adapter between syringe tip and tube of inflation, similar tube with balloon of 50 cubic centimeter capacity for sigmoid colon.

resections. There would be a rather aseptic and clear operative field. After operation, whether an open or an aseptic procedure is done, there would be no tension on the suture lines and no contaminated feces flowing over it thus predisposing to quicker healing. The anastomosed portion of the bowel would be collapsed and at rest which is ideal. In certain inflammatory conditions of the colon or rectum, whether it be primary as diverticulitis, or secondary to a malignant growth, this method of defunctionalization would materially aid its subsidence. It would obviate even the occasional use of the Miller Abbott tube (4) after operation, in large bowel surgery.

CLINICAL EXPERIMENTS

There were many problems to be solved in the practical application of this theory.

The type of balloon to be used, relative to its size, shape, thickness, and durability.

The size of the balloon would necessarily have to be large enough to distend and occlude various portions of the colon. At fresh postmortem, a balloon was placed into the ascending, transverse, and sigmoid colons and inflated. It was found that the amount of air necessary to fill each major portion of colon was dependent on the diameter of the different portions of colon and on the elasticity of the balloon. On using the tube finally selected (Bardex barium enema tube, (Fig. 2)) the ascending and transverse colon distended on inflating with air to 100 cubic centimeters the sigmoid with 50 cubic centimeters of air. The tube was then tried on 2 patients, one with a cecostomy and one with a loop sigmoidostomy. It

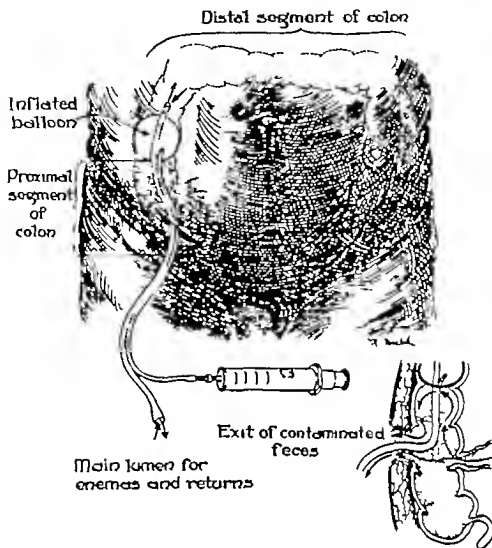


Fig. 3 Application of method described.

was inserted into the respective portion of the colon and the balloon inflated until peristalsis was palpable in the inflating syringe. Under fluoroscopy thin barium was injected around the tube and into the opening in the portion of colon previously mentioned. The balloon was gradually inflated until it obstructed the passage of barium under fluoroscopy. The amount of inflation necessary for obstruction was 90 cubic centimeters in the ascending colon and 40 cubic centimeters of air in the sigmoid.

The ideal shape for the balloon if it is to obstruct the passage of feces, would be cylindrical. This would give the broadest possible surface contact with the least chance of spillage during a peristaltic wave. The cylindrical balloon has not been constructed, as yet.

The rubber from which the balloon is made should be thick enough to withstand a pressure of inflation up to the point where it distends the bowel, plus the increased pressure of colonic con-

tractions. It should also be flexible enough however so that it would conform to the shape of the colon without traumatizing the mucous membrane. The texture of the rubber must be durable and able to withstand the mechanical and chemical contact of intestinal secretions and feces.

A Miller Abbott balloon attached to a rubber tubing was first used (Fig. 1) through a cecostomy. It could be distended to the correct size and its shape conformed readily to the bowel. However it was somewhat light in weight and some barium given by mouth was found to have passed around its margin and into the distal segment of the bowel by x-ray in 1 case. There was not enough pressure exerted by this thin balloon to obstruct the bowel consistently. On keeping this type of balloon distended in the bowel for several days, it was found on 3 occasions, to have ruptured and deflated. A heavier latex condom was then used in which a greater pressure was able to be exerted. The results were more favorable, but not wholly



Fig. 4. X-ray film of tube and inflated balloon in hepatic flexure of colon through cecostomy. Fifteen hour film after taking barium orally. A inflated balloon B obstructed barium in proximal segment of colon. N barium flows past the balloon.

reliable. It was then decided upon to use a No. 30 Bardex barium enema tube with balloon attached. The rubber in the balloon portion is much thicker but it is less distensible and does not conform to the shape of the colon as well. It also exerts a much greater pressure on the bowel wall. This tube was tried through a cecostomy distending the balloon with increasing amounts of air, under fluoroscopy until it obstructed the flow of barium injected into the proximal segment of colon around the tube. It obstructed when the balloon was filled with 90 cubic centimeters of air. A barium meal was then given the patient and x-ray films taken at 15, 24 and 39 hours. All of the barium was seen roentgenologically to come out through the cecostomy around the tube and onto the abdomen. No barium was seen to go beyond the balloon (Figs. 4 and 5). Some barium was then forced through the cecostomy lateral to the tube, under pressure. None leaked beyond the balloon (Fig. 6). About 150 cubic centimeters of light barium was then instilled through the main lumen of the tube into the segment of bowel distal to the balloon. There was no back leakage and the balloon was found to be able to withstand the weight of a column of barium (Fig. 7).



Fig. 5. Same as in Figure 4, 39 hours after per oral barium. A inflated balloon B barium in obstructed cecum and ascending colon—still no leak into the distal segment of colon, C some barium passing through cecostomy around the tube. This cecostomy was tight around the tube. Emptying complete with distillation.

These same experiments were repeated on a loop sigmoidoscopy. In this portion of bowel, a tube with a 40 cubic centimeter capacity of the same design as the Bardex tube was used (Fig. 8, 2). All of the experiments, by x-ray showed that this balloon effectively obstructed the sigmoid (Figs. 8 and 9).

This was definite enough evidence that no feces under normal pressure would pass from that portion of bowel proximal to the balloon to that distal.

The question of impairment of circulation by pressure of the distended balloon on the vessels supplying this segment of colon was considered. It is a known fact that distention of bowel does exert some influence on its circulation. In 1907 Van Zwahlenburg made certain observations on the intestinal blood flow during distention. He found experimentally that the current of flow was slowed in the veins at 90 millimeters of mercury. At 130 millimeters of mercury all circulation ceased. Dragstedt corroborated these findings and on further investigation found that the circulation both arterial and venous, is more vul-



Fig. 6. Original tube and balloon through cecostomy X-ray 7 hours after per oral barium. More barium injected around the tube into the cecum under pressure. Balloon still obstructs flow of barium. *A* Inflated balloon in ascending colon. *B* barium injected into proximal segment of colon obstructed. *C* barium in terminal ileum.

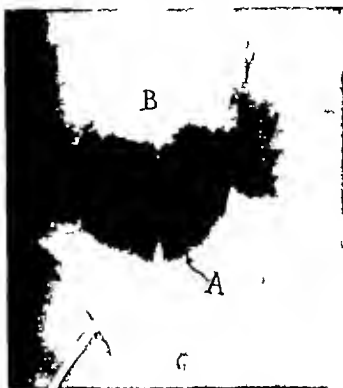


Fig. 7. Tube with balloon in proximal portion of ascending colon through cecostomy. Barium injected through main lumen of tube into distal segment of colon. X-ray film 45 minutes after injection in upright position. *A* Inflated balloon in ascending colon. *B* barium in distal segment of colon. No leak back of barium around the balloon.

nerable to the effects of distention in the duodenum and becomes progressively less so as the rectum is approached. It takes a much higher pressure to occlude the blood supply of the colon than the small intestine. He also observed that prolonged distention gradually increased the flow of blood through the anastomotic vessels until it nearly equaled the original flow.

The large Bardex barium enema balloon when inflated with 90 cubic centimeters of air exerts approximately 105 to 110 millimeters of mercury pressure. It was doubtful whether this balloon could be kept inflated at this pressure for any length of time without disturbing the blood supply of the colon.

In the first case in which the Bardex tube was tried (an inoperable carcinoma of the splenic flexure) it was placed through a cecostomy and into the ascending colon. The balloon was inflated with 40 cubic centimeters of air. The following day an additional 10 cubic centimeters of air was injected and after 6 hours, 10 cubic centimeters was withdrawn. The next day 20 cubic centimeters of air was injected and only 10 cubic centimeters removed after 6 hours. A daily in-

crement of 10 cubic centimeters of air was injected in this manner until 100 cubic centimeters of air were safely in the balloon with no obvious subjective effect on the patient. The air was allowed to remain in for 9 days. The patient had no complaints during this period and there was no clinical evidence, abdominally of impairment of blood supply to the distended portion of the colon. It was, therefore, assumed that the balloon distended with 90 cubic centimeters of air was safe at a pressure of 105 to 110 millimeters of mercury and had no damaging effect on the circulation to the bowel. The same procedure using 40 cubic centimeters of air was done through a sigmoidostomy.

The problem of mucosal necrosis occurring due to the pressure and friction of the rather stiff rubber balloon on the bowel was also considered. This was proved not to be the case in the following manner. The tube was inserted into the sigmoid colon through a sigmoidoscopy opening on the anterior abdominal wall of a patient who had had a preliminary cecostomy and subsequently an abdominoperineal resection. The balloon was placed about 4 centimeters below the skin margin

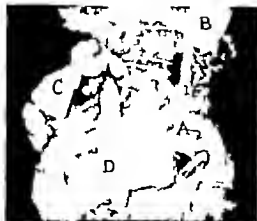


Fig. 8. Small 50 cubic centimeter capacity balloon tube used through loop colostomy in sigmoid colon—14 hour film. 84 year old patient with general gastrointestinal hypomotility. 1. Inflated balloon. B barium in descending colon. C barium in ascending and transverse colon. D barium in small bowel. N barium passes into the recto-sigmoid or rectum.

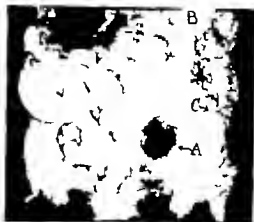


Fig. 9. Same patient as in Figures 8—3 hour film. A. Inflated balloon. B barium in descending colon. C barium passing through sigmoidostomy. D barium passes the balloon into the rectum.

into the sigmoid colon just beneath the level of the fascia. It was inflated with 40 cubic centimeters of air (the necessary amount of air to obstruct this portion of colon) and kept there for 3 days. Each day an endoscope was inserted and the mucosa was inspected. There were no untoward effects upon the mucosa by the balloon.

The bacterial content of the defunctionalized colon was then determined. This was done in 3 patients in the following manner. An enema of 250 cubic centimeters of normal saline solution was given twice daily through the main lumen of tubing into the segment of bowel distal to the balloon. These washings were then sponged off. A few cubic centimeters of the last washing each day were obtained for a culture and colony count. The culture, of course, was already diluted by the washings. This was done on 3 patients. Within 48 hours, the washings returned clear and were devoid of gross fecal particles. In the first patient, the bacterial count dropped from 317 colonies of *Bacillus coli* per plate, to 19 colonies per plate, in the first 6 days. Within the next 4 days, only saline washings being used the count dropped to 3 colonies per plate. This patient had an inoperable carcinoma of the splenic flexure. The second patient had an obstructive carcinoma of the rectum. The washings were done through a cecostomy some of which leaked through the rectum. The predominant organism was *Bacillus proteus* which was reduced from 200 to 8 colonies in 9 days. The third patient had a carcinoma of the rectosigmoid with a permanent loop sigmoido-

scopy. The washings were run through the sigmoid and cultures were obtained from the fluid expelled through the anus. In this patient, the count, at first dropped from 189 colonies *Bacillus coli* to 93 colonies and then abruptly rose. It was found that the balloon had ruptured and that contaminated feces were flowing over through the rectum.

Since the bacteriological studies on these few cases were not carried out with uniform dilutions, it is recognized that the results obtained cannot be conclusive. The consistent observations, however, certainly indicate a tendency toward debacteriolumination. This will be substantiated by further studies.

METHOD OF USE

A cecostomy transverse colostomy or sigmoidostomy is done as a preliminary procedure, according to the position of the lesion. When the bowel has been well sealed off from the peritoneal cavity usually in about 5 days, the tube is placed so that the balloon will be 4 to 5 inches distal to the opening in the bowel (Fig. 3). This prevents the balloon from obstructing the outlet in the colon and also, if it is a cecostomy from obstructing at the ileocecal valve. The tube should be held in place by adhesive taping (Fig. 10). This prevents the balloon from being drawn farther into the colon by peristalsis. The balloon is then inflated with the amount of air previously determined to obstruct the bowel at the segment in which it is inserted (50 cubic centimeters in the ascending colon and 40 cubic centimeters in the sigmoid). Collodion is placed around the wound

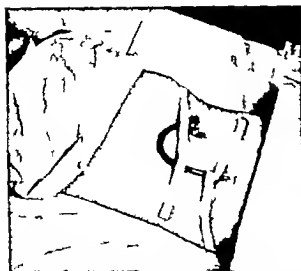


Fig. 10. Tube in place through cecostomy held by adhesive. Position of tube when not in use for irrigations. Main lumen open. This may be attached to drainage bottle.

to prevent excoriation of the skin by feces. Washings are then begun two or three times a day with any type of cleansing solution through the main lumen of the tube (Fig. 11). A titrated solution of sulfasuxidine may be used. These enemas are siphoned off. Within 7 to 10 days, the bowel should be well defunctionalized and ready for the main operative procedure.

During and at least 5 days after the operation if an anastomosis has been done, the tube should be kept intact and inflated. During the entire period it is necessary to test the balloon daily to determine whether it is still intact. This is done by removing the clamp from the balloon portion of the tubing and attaching a loose 20 cubic centimeter syringe. If the balloon is all right, peristalsis will be in evidence by the motion of the obturator of the syringe. Dressings on the abdomen around the tube are changed usually at the time when colon washings are given. If the opening in the large bowel fits very snugly around the tube, it is occasionally necessary to dilate this with a Kelly clamp. When it is thought that the bowel is well healed the balloon is deflated and the tube withdrawn. The colostomy may then be closed. The bowel then assumes its normal continuity.

RESULTS

The clinical experiments for this method of defunctionalization of the colon were done in 6 patients. Four of these were inoperable. Three patients had carcinoma of the rectosigmoid 2 of the splenic flexure, and 1 of the rectum. Four of these patients had cecostomies and 2 loop sigmoidoscopies. The four cecostomies were done for complete obstruction. Both sigmoidoscopies



Fig. 11. Method of washing the distal segment of colon by gravity.

A titrated solution of sulfasuxidine may be used.

were palliative procedures for inoperable malignant lesions.

Three of these patients had the tube inserted and inflated. Barium was given by mouth and serial x-ray pictures taken up to 48 hours. In all 3 no barium passed the inflated balloon. All of it made exit through the respective colostomies. In 2 patients—one a cecostomy and one a sigmoidoscopy—200 cubic centimeters of barium was injected through the bowel opening around the tube into the proximal segment under pressure. No barium passed the balloon by fluoroscopy. In 2 patients, both with colostomies, approximately 400 cubic centimeters of barium were instilled through the main lumen of the tube into the distal segment of bowel. The patient was placed in an upright position for 45 minutes. There was no back flow of barium around the balloon into the proximal segment. This was sufficient evidence to illustrate the effectiveness of a balloon to obstruct the passage of feces in the colon.

There were no complaints by any of these patients of pain due to distention of the colon by the balloon. There was no objective evidence of impairment of blood supply. Mucosal necrosis by the contact of the inflated balloon on the bowel was not observed endoscopically in one patient. It was observed that after repeated washings of the distal segment of bowel for 48 hours, the returns were clear with no macroscopic fecal particles in 3 patients. However the decontamination of the distal segment of colon has not been conclusively proved. Results suggesting debacterIALIZATION have been obtained in preliminary studies. The ideal tube and balloon for this procedure have not, as yet, been constructed.

There were only 2 operable lesions in these 6 cases. The first patient had a carcinoma of the rectosigmoid for which a preliminary cecostomy was done for obstruction. The tube was inserted 5 days before operation and irrigations were done. The patient had an abdominal resection of the rectosigmoid by Hartman's method with a permanent left colostomy. During resection of the lesion, the bowel was inadvertently torn with contamination of the peritoneal cavity. Sulfanilamide was used in the peritoneal cavity. The tube was removed 5 days after operation and the feces allowed to exit from the colostomy. The patient had an uneventful convalescence with no clinical evidence of infection.

The second patient had a carcinoma of the splenic flexure with obstruction. A preliminary cecostomy was done. Fourteen days after this, the tube was inserted and inflated and irrigations with a tetracycline solution of sulfasuxinate were used twice daily. Five days after the insertion of the tube, the splenic flexure with the carcinoma was excised and an end-to-end anastomosis was done. At the time of operation the colon was collapsed. The resected portion was opened and found to be devoid of gross feces. Five days after operation the balloon was deflated and the tube was removed. The patient had an uneventful convalescence.

Another patient with an inoperable carcinoma of the rectum had a preliminary cecostomy for obstruction. On admission to the hospital, the malignant growth was tremendously inflamed so that it was impossible to do a rectal examination. After cecostomy some of the inflammation subsided but the patient developed a diarrhea of 14 to 16 small bloody mucous stools a day. The tube was inserted through the cecostomy and inflated. Within 48 hours, there were no stools

passed per rectum. Within 1 week, rectal examination could be done and it was found that the inflammation had almost completely subsided.

SUMMARY AND CONCLUSION

A new method has been devised to defunctionalize the colon according to Devine's precept. It is an extremely simple procedure, which uses only a colostomy in any portion of the colon proximal to the lesion plus a special double lumen tube with a balloon attached. This functionally divorces one portion of the bowel from the other. Inasmuch as the preliminary colostomy is usually constructed prior to resection of the distal three-fourths of the colon, especially if obstruction is present or imminent, this simplified method of defunctionalization entails no additional operations nor anesthesia. The colon does not have to be disconnected. This procedure may be used for any lesion distal to the beginning of the ascending colon and need not be limited just to the distal portion of the large bowel. It is primarily an aid to resection and anastomosis of portions of the colon. Its possibilities could be extended to use in inflammatory lesions of the large bowel such as acute diverticulitis. As was pointed out in one case it materially aids in the alleviation of the inflammatory process associated with malignant diseases of the colon. This sometimes converts an inoperable into an operable lesion.

This method of defunctionalization of the colon has been used experimentally in 6 cases, with results justifying its continuance with further observation.

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RECTOURINARY FISTULA

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SHORTLY after the close of the Revolutionary War Anthony Fothergill a respected Quaker physician wrote concerning the passage of gas and fecal matter with the urine. 'In young subjects the disease might in some instances, though never without great difficulty be cured by a course of ass's milk and of Bristol water together with a course of wild balsamic injections. In old age though the disease is incurable yet it is of consequence to the physician as well as to the patient and his friends, that a right judgment should be formed of its nature and probable event. This end however can only be obtained from such singular cases being faithfully reported when they occur' (4).

Little progress however was made in the treatment of this distressing malady until the latter half of the nineteenth century when diversion of the fecal stream by means of colostomy was first suggested and practiced (1, 2, 5). By 1888 Harrison Cripps in his classic monograph was able to record 63 collected cases. Forty-eight of these were of inflammatory origin, 9 cancerous, 2 traumatic and the remainder doubtful.

Improvement in diagnostic methods and prompt surgical intervention have materially lessened the incidence of inflammatory fistulas between the rectum and the urinary passages. The advent of perineal and transurethral-prostatic surgery however has more than compensated for this loss. This report deals with 18 cases of rectovesical and rectourethral fistula observed within the last 21 years at the Beth Israel and the Montefiore Hospitals. Thirteen patients were observed and treated by me, 5 cases were discovered at autopsy. There was only 1 female, a woman with a large carcinomatous rectovagino-vesical communication.

ETIOLOGY

The causative factor in these 18 cases was determined as follows: traumatic, 8 cases; inflammatory, 4 cases; neoplastic, 6 cases; doubtful, 1 case.

One traumatic fistula following operation for prostatic carcinoma is also included among the neoplastic cases.

Seven fistulas resulted directly from surgical trauma and another followed an incomplete perineal excision of a large prostatic carcinoma.

From the Genitourinary Surgical Service, Beth Israel Hospital, New York City

In Case 1 a resident surgeon noticed rectal bleeding after passing a sound, and in Case 2 the beak of a cystoscope passed by a general surgeon entered the rectal lumen (10). The perforations during transurethral prostatic resection were also made by junior surgeons and may properly be attributed to limitations in skill.

The perineal prostatectomies, on the other hand were performed by experienced urologists. In one of these (Case 5, Beth Israel Hospital No. 150309) there was no evidence of rectal injury at the time of operation. On the 12th postoperative day there was a brisk hemorrhage into the bladder and on examination a large hiatus was found leading from the bladder into the rectum. This fistula was thought probably due to late necrosis of the thinned out rectal wall.

In Case 6 (Beth Israel Hospital No. 148496) convalescence was uneventful until the 16th postoperative day when an inexperienced nurse asked the patient to insert a rectal thermometer. The thermometer was lost and when later recovered was found to have perforated the anterior rectal wall.

The third fistula, complicating perineal prostatectomy, occurred in a case of prostatic carcinoma operated at a well known urological clinic. Total extirpation was impossible and after a short in-

TABLE I—ETIOLOGY OF RECTOURINARY FISTULA

- A. Traumatic
 1. Instrumental
 - a. Perforation by sound (Case 1)
 - b. Perforation by cystoscope (Case 2)
 2. Postprostatectomy
 - a. Transurethral resection (Cases 3, 4)
 - b. Perineal prostatectomy
 - (1) Benign (Cases 5, 6, 18)
 - (2) Carcinoma (Case 7)
- B. Inflammatory
 1. Acute infection
 - a. Prostatic abscess (Case 8)
 - b. Perirectal abscess, Imperforate anus (Case 9)
 2. Chronic: Pelvis, Rectovagino-vesical fistula (Case 10)
 3. Tuberculosis of bladder with calculus (Case 11)
- C. Neoplastic
 1. Prostatic carcinoma, perineal operation (Case 7)
 2. Rectal carcinoma discovered at autopsy (Cases 12, 13, 14, 15)
 3. Ovarian carcinoma, rectovagino-vesical fistula discovered at autopsy (Case 16)
- D. Doubtful
 1. separate fistulas (Case 17)



Fig. Case 8. Radio-opaque solution injected into bladder outlining rectum and colon.

terval, gas and fecal matter appeared in the urine.

SYMPTOMS AND DIAGNOSIS

The passage of gas and fecal matter with the urine or the presence of urine in the rectum indicates the existence of a communication between the bowel and the urinary passages. Gas alone in the urine however is known to occur in certain rare bladder infections. Some fistulas possess a ball-valve-like action, allowing free passage in but 1 direction, as in Case 10 in which fecal matter seeped into the bladder without demonstrable urinary leakage into the rectum. The presence of highly infective fecal matter in the bladder usually gives rise to cystitis and pyelonephritis with their attendant symptoms.

The injection of colored or radio-opaque solutions into the bladder or rectum is also of value in proving the existence of an abnormal communication. However short fistulas of large diameter between the rectum and the urinary passages are themselves rarely visualized on the x-ray film. A contrast solution, injected into the bladder or urethra, flows freely through such a wide communication, speedily outlining the rectum and sigmoid colon (Fig. 1). On the other hand, the longer and more tortuous fistulas, due usually to inflammatory disease, may often be clearly de-

TABLE II.—ACUTE RECTOURINARY FISTULA—6 CASES

Case	Cause	Treatment	Result
	Passage of sound	Urethral retention catheter	Cured
	Cystoscopy	Urethral retention catheter	Cured
3	Transurethral prostatectomy	Urethral retention catheter Colostomy Suprapubic cystostomy	Failed due to carcinoma of lung
5	Perineal prostatectomy	Urethral and suprapubic catheter	Failed
	Perineal prostatectomy Postoperative thrombotic perforation	Urethral and suprapubic catheter	Failed
6	Prostatic abscess perforating into rectum	Perineal drainage of abscess and urethral retention catheter	Cured

lined by the ingestion of barium (Fig. 2) or the injection of iodized oil.

The size and location of a fistula are accurately determined by rectal palpation and by cystoscopic and proctoscopic examination. Punch biopsy often establishes the presence of neoplasm or tuberculosis. The possibility of multiple fistulas should not be overlooked (Case 17).

TREATMENT

Acute fistula. The immediate treatment of a recent rectourinary fistula is concerned with (1) control of hemorrhage, (2) urinary drainage by urethral or suprapubic catheter (3) constipation by diet and drugs, (4) intestinal bacteriostasis (sulfasundme sulfaguanidine).

Results. Simple measures, such as an indwelling catheter and induced constipation, resulted in permanent closure in 3 of the 6 cases of acute fistula (Table II).

On the other hand a rectourethral fistula, 1 centimeter in diameter resulting from a transurethral prostatectomy persisted despite colostomy and suprapubic cystostomy. Reparative perineal operation was prevented in this case by the coincidental development of a fatal pulmonary carcinoma (Case 3). This fistula as well as the two which complicated perineal prostatectomy (Cases 5, 6) were short and of large diameter, the posterior urethra and rectum being in close apposition. Such fistulas are less likely to close spontaneously than are the long narrow tortuous tracts usually resulting from inflammatory disease (3, 7).

Both fistulas which followed perineal prostatectomy failed to heal despite urethral and suprapubic catheter drainage but were later cured by perineal reparative operation.

TABLE III—CHRONIC RECTOURINARY FISTULA
—9 CASES

Case	Cause	Treatment	Result
0	Petrectal abscess Imperforate anus	Colostomy	Cured
	Chronic Belzils with ileo- rectovesical fistula	Sigmoid colectomy Ileotransverse colo- stomy with excision of distal ileum. Supra- pubic cystostomy	Improved
	Vesical and renal tuber- culosis with calculus	Suprapubic cysto- lithotomy	Failed Died
4	Transurethral resection	Indwelling urethral catheter	Cured
5	Perineal prostatectomy	Sulfasuxidine. Supra- pubic cystostomy Perineal repair	Cured
6	Perineal prostatectomy Postoperative ther- mostatic perforation	Sulfasuxidine. Supra- pubic cystostomy Perineal repair	Cured
7	Perineal prostatectomy for prostatic carcinoma	Colostomy Radio- therapy Bilateral orchiectomy	Failed Died
7	Unknown	Colostomy Suprapubic cystostomy Perineal repair	Cured
18	Perineal prostatectomy	Perineal repair supra- pubic cystostomy	Cured

Chronic fistula (Table III) The treatment of chronic rectourinary fistula may be considered under 3 headings (1) diversion of the fecal stream, (2) diversion of the urinary stream (3) surgical repair.

Diversion of the fecal stream by means of colostomy can be effective only if the colostomy is complete and situated proximal to the site of the fistula. For example, in Case 10 in which there was an ileorectovesical communication a colostomy could obviously not succeed in diverting the ileal contents from the bladder. In this instance, an ileotransverse colostomy with excision of the distal ileum in addition to a sigmoid colostomy proved effective.

Diversion of the fecal stream is commonly followed by prompt amelioration of the urinary infection and by an improvement in general health. Sulfu drugs are efficacious. Control of urinary infection may result in spontaneous closure especially in fistulas of inflammatory origin (Case 9).

Colostomy is urged by some authors as a routine measure preliminary to reparative closure (6). Although this has doubtless been of value in the past, the effectiveness of bacteriostatic drugs, such as sulfasuxidine and sulfaguanidine, has led me to believe that now colostomy may often be unnecessary. In 3 patients (Cases 5, 6, 18) a perineal reparative operation was done after preliminary preparation with sulfasuxidine.



Fig. 2. Case 10. Rectovesical fistula visualized following barium enema. Note barium in bladder. An ileotransverse colostomy had been made.

Both fistulas were cured without the additional risk and distress of a colostomy.

Diversion of the urinary stream by means of an indwelling urethral catheter or a suprapubic cystostomy is sometimes followed by spontaneous closure in both acute and chronic fistulas (Cases 1, 2, 4). The importance of preliminary suprapubic cystostomy in cases in which a plastic reparative operation is done has been stressed (6, 9). Free urinary drainage prevents irritation and undue tension on the freshly made vesical and urethral suture lines.

Surgical repair. Radical operation for the cure of rectourinary fistula consists of exposing and excising the fistulous tract and competently closing the resultant openings in the rectum and urinary passages. A rectovesical fistula may be approached abdominally or perineally. The perineal route is preferable except in the very high fistulas or in the presence of a complicating intra-abdominal lesion.

Rectourethral fistulas should be attacked from below (8, 9). The perineal operation offers good anatomical exposure and a lower morbidity and mortality.

The openings in the bladder or urethra and in the rectum, resulting from excision of the fistula

are closed in 3 layers, without tension. Plain catgut is used for the mucosal layer of the bladder and chromic catgut for all the other suture lines. A wedge of muscular and fibrous tissue should be interposed between the sutured openings in the bladder and rectum.

The rectal suture line has been ingeniously eliminated by Young's operation (9) in which the rectum is mobilized well above the fistula and dissected downward so that the fistulous defect is pulled outside the anus. The excess rectal mucosa including the opening is then amputated and the cut edges are sutured to the anal skin margin as in the Whitehead operation. The advantage of this procedure in forming a solid rectal wall is obvious. Unfortunately however it is not always feasible especially if the fistula is high and the rectum adherent. In 2 cases (Cases 15-17) it was impossible to mobilize the rectum sufficiently to exteriorize the fistulous defects. There was, however, enough downward dislocation of the rectum to prevent apposition of the freshly made suture lines. The continuity of the rectal sphincter was preserved. Its anterior half was freed and sutured to the prostatic capsule interposing a muscular mass between the rectal and urethral suture lines.

Results. There were 2 failures among the 9 treated cases of chronic fistula (Table III). One was in a patient with advanced renal and vesical tuberculosis and the other was a fistula following perineal prostatectomy for a large prostatic carcinoma. The latter communication persisted to autopsy despite temporary improvement in health following sigmoid colectomy and bilateral orchidectomy. Six of the 9 chronic fistulas were cured and 1 has been greatly improved. A recto-urethral communication resulting from a perirectal abscess closed spontaneously almost 10 years after colectomy (Case 9). Another fistula which followed a transurethral resection healed promptly with an indwelling catheter (Case 4).

Five patients were subjected to radical reparative surgery. One of these was operated upon abdominally, the rest by the perineal approach.

CASE 1. (Montefiore Hospital No. 23 56.) This 52-year-old man entered the Montefiore Hospital on January 7, 1941, complaining of the passage of fecal matter and gas in the urine. He had suffered from lower abdominal cramps and diarrhea, associated with nausea and vomiting, for almost 9 years. In December 1932, he submitted to an appendectomy and cholecystectomy at the Metropolitan Hospital. The pathological report as chronic cholecystitis and chronic granulomatous appendicitis. The symptoms continued, however, and in May 1940, the patient noticed that he was passing food particles and gas in his urine. At local sanatorium on December 23, 1940, an attempted attempt was made to close the supposed

rectovesical fistula. The bladder was opened suprapubically, the edges of the fistula freshened and closed with several layers of sutures passed through pyelostomatous tissue surrounding the fistula. These sutures gave promptly and since then fecal matter and gas had been passed through the urethra and through the persistent suprapubic fistula.

Physical examination and roentgenographic study at the Montefiore Hospital established the existence of an ileorectovesical fistula due probably to chronic ileitis.

The abdomen was explored on March 5, 1941, and large inflammatory mass involving the rectum, bladder and terminal ileum, was found. The ileum as dissected from the bladder cutting across the fat in. The densely adherent rectum and bladder however could not be separated. The terminal ileum distal to the fistula as completely obstructed by granulomatous and fibrous tissue (chronic ileitis). The fistulous openings in the bladder and ileum were closed and a side-to-side ileotransverse colostomy as done. A double-barreled sigmoid colectomy and suprapubic cystostomy were also done. The suture line closing the fistulous opening in the ileum gave promptly and fecal feces were discharged through the lower end of the wound and into the bladder.

At second operation on April 9, 1941, the ileum as transected distal to the ileotransverse colostomy the ends being closed in 3 layers. The suture lines held, and on more fecal matter or gas has since appeared in the bladder or from the wound. The urinary infection quickly subsided. Methylene blue injected into the lower sigmoid colostomy opening on April 6 promptly appeared in the bladder. On repetition 1 week later, however, no blue appeared in the bladder. The suprapubic incision closed rapidly following removal of the cystostomy tube and on May 6, 1941, the patient left the hospital considerably improved with functioning sigmoid colostomy.

The patient entered the Beth Israel Hospital (No. 3309) on June 20, 1941. He had been ill for the past month and repeated tests failed to demonstrate any communication between the bladder and the rectum. At cystoscopy on July 20, 1941, shallow pouch as seen at the right side of the trigone. This pouch, representing the ut. of the fistula, appeared well healed, and attempts to pass catheter were unsuccessful. Blue solution injected into the bladder under pressure, did not appear in the rectum. Since there was now no evidence of any fistulous communication, the sigmoid colectomy as closed by Dr. S. Standard on July 24, 1941. The colostomy remained closed, but on the 6th postoperative day the patient again noticed the passage of gas through the urethra. A barium enema proved the existence of rectovesical communication, and on July 8 transverse colostomy about 4 inches distal to the ileotransverse colostomy as made by Dr. Standard. The patient left the hospital on August 4, 1941.

Since leaving the hospital he has voided normally and has never passed urine through the rectum. Colored solution injected into the bladder also did not appear in the rectum. On the other hand, during 1941, colored solution did seep into the bladder following distention enema. In 1943, however, colored enemas no longer appeared in the urine. The fistula had been electrocoagulated cystoscopically and at subsequent cystoscopic examinations no evidence of communication could be found. On December 1, 1943, however, an effervescent blue solution as injected into the rectum, and short time later the patient passed few colored gas bubbles through the urethra. A perineal reparative operation has been advised.

This case of ileorectovesical fistula illustrates the importance of accurately determining the

location of the fistula. A previous attempt at operative closure was doomed by failure of the surgeon to recognize the participation of the ileum in the fistula.

Following diversion of the fecal stream by ileo-transverse colostomy with exclusion and sigmoid colostomy the rectovesical fistula contracted so that urine never leaked into the rectum. On the other hand colored enemas flowed freely into the bladder. The fistula contracted still further so that distention enemas no longer appeared in the urine. The fistula was apparently water tight in both directions. However its patency to gas was proved by the injection of an effervescent solution into the rectum.

CASE 5 (Beth Israel Hospital No. 150309.) This 63 year old man had undergone a perineal prostatectomy on October 8, 1942. On the 12th postoperative day there was a brisk hemorrhage into the bladder and on examination a large communication was found between the bladder and the rectum.

The patient re-entered the hospital on February 4, 1943 for the repair of a circular rectovesical fistula about 3 centimeters in diameter. He suffered from chronic azotemia and was prepared preoperatively with intravenous fluids, a blood transfusion, and a 2 weeks course of sulfasimidine a total of 67.5 grams being administered.

On February 18 the fistula was exposed perineally and the rectum was separated from the bladder. The vesical opening was closed in 2 layers. The rectum was mobilized well above the fistula and pulled downward. The opening in the rectum, however, could not be exteriorized and was closed with 3 layers of fine chromic sutures. The rectal sphincter was partially mobilized and sutured to the prostatic capsule interposing a muscular wedge between the vesical and rectal suture lines. A suprapubic cystostomy had previously been done.

The postoperative course was uneventful the perineal wound healing well. Colored solution injected through the urethra on the 12th postoperative day appeared through the suprapubic tube but not in the rectum. The suprapubic tube was removed but a small sinus persisted which was operatively closed on March 11. Sulfadiazine was administered, and on March 20 the patient left the hospital voiding through the urethra with good control. There was no evidence of rectovesical fistula, and the suprapubic and perineal wounds were healed. A moderate degree of azotemia persisted. The patient was fairly well when seen on October 12 and November 4, 1943 despite a chronic pyelonephritis with azotemia. There was no rectovesical communication. Rectal control was normal.

The patient re-entered the hospital on January 20, 1944 with severe azotemia and acidosis. The rectal wall was firm, but there was a small perineal sinus from which pus and urine drained. Despite temporary improvement the patient died on January 31.

At autopsy the site of the former rectovesical fistula was indicated by a firmly healed radiating gray scar in the rectum. A small perineal fistula communicating with the posterior urethra was found. The right kidney was small weighing 25 gram. The pelvis and calyces were dilated but little parenchyma remained. The left kidney was also hydronephrotic the pelvis and calyces being dilated to 1.5 cm. The rectum was filled with abscesses.

CASE 6 (Beth Israel Hospital No. 15046.) This 61 year old man was subjected to a perineal prostatectomy on

October 4, 1941. The postoperative course was uneventful until the 16th postoperative day when the anterior wall of the rectum was perforated by a thermometer. The patient left the hospital, however on October 20 voiding through the urethra with good control. At times he noticed the passage of urine through the rectum.

The patient re-entered the hospital on December 7, 1942 for surgical repair of his rectourethral fistula. He was prepared with sulfasimidine 30 grams being administered in 4 days. On December 17 the fistula was excised by the perineal route, the bladder being separated from the rectum. The opening in the urethra was closed with 3 layers of chromic catgut sutures and then reinforced with 2 additional layers. The rectum was mobilized well above the site of the fistula and pulled downward, thus exteriorizing the fistulous opening. The redundant rectal mucosa was then excised and the cut edges were sutured to the anal skin. In addition a suprapubic cystostomy was carried out.

The postoperative course was smooth the perineal wound healing well. The suprapubic tube was removed on the 33d postoperative day and 3 days later the suprapubic fistula was healed.

The patient left the hospital on January 12, 1943 voiding through the urethra with good control. There was no evidence of any rectourethral communication and the perineal and suprapubic wounds were healed. The fistula has remained healed, and the patient was well when last seen on February 5, 1944. Rectal examination revealed no evidence of fistula. Rectal control was normal.

CASE 17 (Beth Israel Hospital No. 158216.) This 49 year old man entered the hospital on November 12, 1943 with a large rectourethral fistula easily admitting the index finger and a second smaller fistula, 0.5 centimeter in diameter between the rectum and the trigone. He had been ill for 16 years complaining of abdominal pain, weakness, and anemia. Eight years ago he suffered from repeated rectal hemorrhages and shortly thereafter an anal fistula was discovered and excised. In May, 1941 he suddenly began to pass gas, fecal matter and blood through the urethra and at the same time blood and urine were discharged from the rectum. Rectovesical fistulas were found and a bilateral vasectomy was done at the Brooklyn Jewish Hospital. The patient was told that no operation would be done for the cure of the fistulas.

The patient then entered the New York Hospital complaining of severe pain in the urethra. Despite careful study including biopsy the cause of the fistulas could not be determined. At proctoscopy the instrument could be inserted from the rectum into the bladder. It was felt that the fistula was far too large to attempt repair and that, even if successful urinary incontinence would be likely. A double barreled sigmoid colostomy was done with some relief. Fecal matter and gas no longer appeared in the urine. Most of the urine however continued to flow through the rectum, when first seen by the author on November 1, 1943.

Rectal examination disclosed a large rectourethral fistula and a second smaller rectovesical fistula. Lactography urography showed a normal upper urinary tract and by cystoscopy confirmation of the size and location of the fistulas was made.

Suprapubic cystostomy was done on November 15 and immediately thereafter perineal repair was attempted. The large rectourethral fistula was exposed and excised. The visualization of the rectovesical fistula, however, was accomplished only with great difficulty. The rectum was dissected from the bladder well above the perineal fistula and displaced downward. The inferior fistulous opening was thus exteriorized, the redundant rectal mucosa being

amputated. The superior fistula, however, could not be brought down far enough for exteriorization. This opening in the rectum was closed in 3 layers with interrupted chromic sutures. The opening in the urethra was closed in 3 layers of interrupted chromic sutures over a Foley catheter. The opening in the bladder was also closed in 3 layers with interrupted chromic sutures and reinforced with remnants of the prostatic capsule. The anterior half of the anal sphincter was mobilized and sutured to the prostatic capsule, interposing a muscular wedge between the rectal and the urinary suture lines.

The postoperative course was smooth, the wounds healing promptly. The patient left the hospital on November 7 with the cystostomy tube in place. On December 4, the cystostomy tube was clamped and blue solution injected into the bladder. The solution was voided through the urethra with good control and none appeared in the rectum. Examination disclosed a solid rectal wall. A week later blue solution was injected into the rectum and none appeared in the urine. The suprapubic tube was removed, and on December 5 the suprapubic wound was healed. Since then the patient has voided through the urethra with good control and there has been no leakage into the rectum. On December 5 the wounds were healed and the rectal wall was firm. A colored effervescent enema did not appear in the urine.

CASE 8. (B I H No. 6795.) This 6-year-old boy was subjected to perineal proctostomy on March 9, 1943, in a southwestern hospital. He developed a gas infection with gangrene and necrosis of the perineal wound and scrotum, with crepitation up to the clavicle on both sides. With incision, radiotherapy and Radline vacuol antitoxin cleared up the gas infection. The wound healed by granulation but there was persistent rectourethral fistula.

On January 3, 1944, the original surgeon made an effort to dissect out the fistulous tract but without success. On February 2, the urethral fistula was electrocoagulated transurethrally without benefit.

When I first saw the patient on March 30, 1944, he voided about half his urine through the rectum. On examination, an opening could be felt in the anterior rectal wall 3 centimeters above the anus. The perineum and scrotum were largely replaced by scar tissue. Cystourethroscopy visualized fistulous opening in the distal portion of the posterior urethra. There was also a small perineal fistula. Rectal control was normal, but there was partial urinary incontinence.

Following preliminary course of sulfasuxidine, the fistula was exposed and excised perineally on April 3, 1944. The rectum was mobilized and separated from the bladder and urethra. The defect in the urethra was sutured in 3 layers over catheter. The rectum was dissected downward, the fistulous opening exteriorized, and the redundant mucosa excised. The cut edges were sutured to the anal skin. The perineal wound was left wide open and suprapubic cystostomy was done.

Convalescence was smooth, the perineal wound filling in rapidly with granulation tissue. The suprapubic tube was removed on the 5th postoperative day and the suprapubic stoma was healed in 24 hours. The patient voided through the urethra with good stream. There was no leakage through the perineum and the rectal wall was solid. Blue solution injected into the bladder was voided through the urethra and did not appear in the rectum or in the perineum. There was, however, partial urinary incontinence.

The patient left the hospital on April 26, 1944, with good rectal control. The perineum was practically healed and the fistula cured.

SUMMARY

Surgical trauma and neoplasm were the most frequent causes in 18 cases of rectovesical and rectourethral fistula.

The passage of gas and fecal matter with the urine or the presence of urine in the rectum indicated a communication between the bowel and the urinary passages. The size and location of the fistulas were determined by rectal palpation and by cystoscopic and proctoscopic examinations. The injection of colored and radio-opaque solutions served as a valuable confirmatory diagnostic measure. In 1 case an effervescent colored enema demonstrated a tiny communication when other methods failed.

Six rectourethral fistulas were observed during the acute stage shortly after perforation. The immediate treatment of such a fistula was concerned with control of hemorrhage, adequate urinary drainage induced constipation, and intestinal bacteriostasis. Three of the acute fistulas were cured by these simple measures.

Five of the 9 cases of chronic rectourethral fistula were subjected to radical reparative operation. Suprapubic cystostomy was a routine preliminary measure. On the other hand, the preoperative administration of sulfasuxidine eliminated the need for colostomy in 3 cases. Colostomy served as an effective palliative measure in 3 inoperable cases.

An ileorectovesical fistula was operated upon abdominally and 4 rectourethral fistulas were successfully repaired by the Young perineal technique. A modification was introduced in 2 cases in which the rectal fistulous opening could not be exteriorized. The anterior half of the preserved rectal sphincter was mobilized and sutured to the prostatic capsule, interposing a muscular wedge between the vesical and rectal sphincter lines. Rectal control was unaffected.

CONCLUSIONS

Rectourethral fistulas due to trauma or acute inflammatory disease frequently heal with conservative treatment. On the other hand, those which are caused by neoplasm offer a grave prognosis.

Chronic rectovesical and rectourethral fistulas are best approached and repaired by the perineal route. The fistulous opening in the rectum can often be exteriorized and excised with the redundant mucous membrane. If this is not feasible, the freshly sutured defects in the bladder and rectum should be separated by an interposed muscular wedge. The rectal sphincter can safely be used for this purpose.

Suprapubic cystostomy is indicated prior to radical reparative operation. On the other hand preoperative administration of sulfasuxidine has enabled the author to abandon preliminary colostomy as a routine measure.

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THE USE OF VENOUS TOURNIQUETS AS AN AID TO THE DIAGNOSIS OF INCIPIENT TRAUMATIC SHOCK

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THE need for a method that will aid in the detection of incipient traumatic shock has been repeatedly emphasized. The decline in blood volume which occurs in the early stages of traumatic shock is associated with vasoconstriction and a fall in cardiac output. Because of vasoconstriction the arterial pressure usually does not decline until a later stage of shock has been reached. It is obvious, then, that it is desirable to diagnose early or incipient shock before the arterial pressure declines. The presence or absence of alterations in the pulse rate and in the concentration of the red blood corpuscles may be misleading. It is agreed by most workers in this field that one should treat shock according to the extent of injury and blood loss and the general clinical picture rather than wait for alterations in the blood pressure or pulse rate or concentration of the red corpuscles.

A test for incipient shock, if it is to be of practical value, should be simple, rapid, and reliable. The method to be described has been employed in the accident room of the Johns Hopkins Hospital for almost a year and has been of practical value. The method is simple but is not so rapid as might be desired. In a few cases it has indicated incipient shock of a greater degree than existed as judged by the subsequent course of the patient. On the other hand, the test has not failed to indicate incipient shock when it was present.

The principle underlying the method is that of reducing temporarily the effective volume of circulating blood by trapping part of the blood in the lower extremities by the application of venous tourniquets. It was reasoned that in the presence of a previous reduction in blood volume a further decline might not allow compensatory vasoconstriction to maintain the arterial pressure at the normal level.

The majority of the patients were young adults and most of them had been in good health. Patients who had a systolic pressure which was distinctly below normal were not included in the

study. Although previous blood pressure determinations had not been performed systolic levels of 104 millimeters of mercury and above were assumed to be normal. As soon as the general condition of the patient had been noted, blood pressure cuffs were applied as high as possible about both upper thighs. Some difficulty was encountered in the earlier cases in which ordinary blood pressure cuffs were applied to the thighs. Because of the conical shape of the thigh and variation in size in different patients the cuffs had a tendency to slip downward from the original position on the thigh. These difficulties were overcome by lengthening the cloth portion of the cuffs by four feet. The cuffs on the two thighs were inflated to a degree slightly in excess of the previously determined diastolic level. These two cuffs were connected in such a manner that they could be inflated simultaneously. This inflation was maintained for 5 or 6 minutes, and during this time the blood pressure in one of the arms was determined at minute intervals. The cuffs on the thighs were then deflated and several additional determinations of the blood pressure were made.

The results are divided into five groups according to the percentage of reduction in the systolic pressure that accompanied the inflation of the cuffs on the thighs. The arbitrary divisions are as follows: (1) 0 to 5 per cent reduction (2) 5 to 10 per cent reduction (3) 10 to 17 per cent reduction (4) 17 to 25 per cent reduction and (5) 25 per cent or more. These results are given in Tables I, II, III, IV and V.

The control subjects showed little reduction in the systolic pressure in association with the inflation of the cuffs. These subjects were ambulatory normal young adults who were allowed to remain in a reclining position for 5 to 10 minutes before readings were begun. Inflation of the thigh cuffs in 17 of these subjects produced either no fall in systolic pressure or a fall amounting to less than 5 per cent of the control level. In the remaining 2 subjects the fall in systolic pressure was 6 per cent in 1 and 7 per cent of the control value in the other. In 5 of the 8 blood donors there was less than a 5 per cent reduction in the systolic pressure. Nine hundred cubic centimeters of blood

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TABLE I.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 5 PER CENT OR LESS FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg	Treatment	Remarks
	Controls	Normal	None	
5	Blood donor	Normal	None	500 c.c. donations
	Leaking ectopic pregnancy	20/84. Fall to 90/60 during operation	500 c.c. blood	Leaking ectopic with 50 c.c. blood in peritoneal cavity. Recovery
	Struck by automobile. Question of ruptured viscera	Normal	None	After period of observation symptoms cleared spontaneously and patients discharged
	Vaginal bleeding from incomplete abortion	20/74	None	Given course of pituitrin. Discharged
	Contusion of arm in washing machine wringer	16/6	None	Discharged well. No sign of serious injury to arm
	Large laceration forehead. Moderate bleeding. Struck by automobile	132/36	None	Discharged well. No fracture of skull or intracranial injury
	1st, 2nd, and 3rd degree burns of 20 per cent body surface	2/72	Sedum lactate 500 c.c. Plasma 500 and saline 500	Eventually grafted over small area. Discharged well
	Compound fracture tibia and fibula	65/34	None	Recovery
	Stab wound chest wall	14/00	None	Recovery
3	Laceration scalp	Normal	None	Recovery

had been removed from 1 of the 3 remaining subjects. A detailed description of the other results is unnecessary since they are given in the tables. In studying these tables it is apparent that those patients with the most extensive injuries and the greatest loss of blood usually showed the greatest decline in the systolic arterial pressure when the cuffs were inflated. Furthermore, it was usually those patients who exhibited the greatest decline in arterial pressure who required the largest volume of intravenous fluids. In almost all instances the systolic pressure returned to or almost to the previous control level as soon as the constriction on the thighs was released.

In a number of cases the pulse rate increased when the venous tourniquets were applied. This alteration however was less constant than the decline in the systolic pressure.

Only one patient with burns was studied. This patient was seen a few minutes after the injury. Despite the fact that approximately 20 per cent of the body surface had been burned there was little decline in the blood pressure following application of the tourniquets. Additional studies on this type of injury are indicated.

Studies were carried out on several patients in whom the blood pressure was at shock level at the time of studies. A considerable decline in blood pressure was noted after application of tourniquets. These cases are not included in the tables.

As stated previously, in traumatic shock the blood volume and cardiac output decline before

the fall in blood pressure occurs. In recovery from traumatic shock after the administration of blood and blood substitutes, the blood pressure returns to normal before the blood volume has been restored to its previous level. It has not been fully appreciated that one should not be content with effecting a return of the blood pressure to normal but should continue treatment until an adequate blood volume has been restored. Churchill recently has stressed the importance of determining when the injured patient is in a stabilized state and can withstand operation or transportation without the development of peripheral circulatory failure. Although the test which has been described has not been adequately studied from this viewpoint it is likely that the method will supply useful information.

In connection with these studies the experiments of Ebert and Stead are of interest. These investigators while studying the rationale for the application of venous tourniquets in the treatment of cardiac failure proved that a considerable quantity of blood could be trapped in the extremities by the use of venous tourniquets. When tourniquets were applied to both upper thighs and one arm for a period of 7 to 10 minutes the amount of blood contained in these extremities at the end of this time averaged 29 per cent of the previously determined total blood volume. From these observations it is clear that further reduction of the circulating blood volume of an injured patient by this method could reduce the blood

TABLE II.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 5 TO 10 PER CENT FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg	Treatment	Remarks
	Controls	Normal	None	No symptoms. One showed fall in systolic pressure of 6 per cent, the other 7 per cent.
1	Blind donor (see p. 50)	Normal	None	Fatigue and sweating. Quick recovery.
	Stab wound of thorax with evidence of pleural perforation but no hemothorax or pneumothorax	Normal	None	Weakness. One admitted overnight.
	Multicystic jagged lacerations of scalp. Moderate bleeding	114/82	None	Lacerations sutured. Discharged.
	Fracture tibia and fibula	114/80	None	Recovery.
	Gumbet wound abdomen and left forearm. Perforations pyramus	130/78	1,500 saline	Recovery.

TABLE III.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 10 TO 17 PER CENT FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg	Treatment	Remarks
	Stab wound of chest and abdomen. Hemothorax and hemoabdomen	106/58	500 blood. Fluid during test.	Small amount of blood given. No blood aspirated from thorax.
	Stab wound of abdomen with laceration of liver	70/114	2,000 intravenous fluids	Moderate bleeding from lacerated liver.
	Stab wound of abdomen with perforation of colon	105/70	1,500 saline and glucose. Fluid during test.	Exploration, suture colon, recovery.
	Bullet wound of chest and liver	58/90	None	No developed signs of serious internal hemorrhage. Observed 4 days. Discharged well.
	Stab wound of chest with hemothorax	106/70	None	Developed hemothorax but no dyspnea or signs of mediastinal shift.
	Blunt compound fracture both lower legs	86/52	1,500 intravenous fluids	Fractures reduced under ether anesthesia and casts applied. Discharged well.
	Intracranial injury	106/85	None	Unstable to ward. Hours later, still unconscious. Died several days later.
	Stab wound chest. Slight hemothorax	144/86	None	Recovery.
	Gumbet wounds of abdomen and chest. Injury spleen, stomach, etc.	114/70	1,500 blood	Blood pressure dropped to 70/30 during operation. Died subsequently.
	Subcutaneous fracture femur	86/54	500 saline and glucose	Recovery.

TABLE IV.—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 17 TO 25 PER CENT FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg	Treatment	Remarks
	Bullet wounds of abdomen and arm. Multiple perforations of ilium and ischium	86/30	1,500 blood. Glucose and saline also	Exploration. Recovery. Small intestine. Blood pressure fell to 72/34 during operation. Recovery.
	Extensive laceration of head. Moderate blood loss	106/	None. 1,500 saline and glucose after operation.	Lacerations repaired under anesthesia. Sutured on verge of non-apnea shock at time of test.
	Penetrating abdominal wound. Wound face	11/80	1,500 saline glucose solution	Blood pressure fell to 70/30 during operation. Recovery.
	Gumbet wound of femur	114/51	None	Recovery.

TABLE I—DECLINE IN SYSTOLIC ARTERIAL BLOOD PRESSURE OF 25 PER CENT OR GREATER FOLLOWING APPLICATION OF VENOUS TOURNIQUETS

No. of cases	Type of disorder	Control blood pressure mm. Hg	Treatment	Remarks
	Bullet wound of abdomen with perforation of stomach. 500 c.c. blood in lower peritoneal cavity	36/80	500 c. saline and glucose. 500 c.c. plasma 500 c. blood	Exploration, suture perforation. Recovery
	Bullet wound of abdomen with perforation of sigmoid and mesentery and multiple perforations of ileum	30/68	500 intravenous fluids. 500 c.c. blood	Resection portion sigmoid and ileum. Blood pressure dropped to 80/55 during operation. Recovery
	Stab wound of abdomen with division of deep inferior epigastric artery	3/66	1,000 c. intravenous fluids 500 c. blood	Exploration. Intra-abdominal laceration although peritoneal cavity had been entered. Recovery
	Bullet wound of thorax with hemothorax	14/58	750 intravenous fluids	Two days later 450 c. bloody fluid aspirated from chest. 500 c. more on following day drained. Recovered
	Struck by stone. Fracture ribs, 3 ribs, sacrum, pelvis, and pubic ramus	04/50	500 c. plasma. Fluids by mouth	Treated with bed rest. General condition remained good. Recovered
	Severe spinal bleeding from incomplete abortion	/48	1,000 blood	Blood pressure good on admission. Bleeding in small amounts. Hemoglobin, 14 per cent. N. Given course of penicillin. Passed placenta hospital 4 days later wt. 11
	Penetrating chest wound. Laceration lung	1/80	500 saline, 500 c.c. blood	Blood pressure fell to 70/54 with tourniquets and to 70/50 during the operation. Recovery

volume sufficiently to produce a fall in arterial pressure before it would have occurred in the ordinary sequence of changes in the development of shock.

In summary a method has been described which appears to be useful in the diagnosis of early shock before a significant decline in the arterial pressure has occurred. The method consists in the application of blood pressure cuffs to the upper thighs and the inflation of the cuffs

to a point slightly above the diastolic pressure level. An associated fall in arterial pressure if present may give a false indication of the presence of shock, but apparently it is correct in indicating incipient traumatic shock when it exists.

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LABORATORY ROUTINE FOR FLUID ELECTROLYTE AND PROTEIN CONTROL IN SURGICAL PATIENTS

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EARLY in 1836 Bright observed in his studies on nephritis that the protein concentration of the blood plasma was low. Cantary (1891) found that this deficiency was due more to a low serum albumin than to a reduced globulin level so that the albumin globulin ratio normally 1.5 to 2.5 fell below 1. During the ensuing years this reduction in the albumin globulin ratio was observed in diseases other than nephritis. Gram found wide variations in the plasma proteins in various types of liver carcinoma and we have repeatedly observed an early drop in albumin in dogs following ligation of the common bile duct. Gernet, and Gilbert and Churay were among the first to observe decreases in the total plasma protein level in patients with cirrhosis of the liver while Myers and Keefer studied 16 cases of cirrhosis and 14 cases of other types of liver disease showing consistent reduction in the blood protein level. Tumen and Bokus, and Foley with others found this reduction in plasma protein to be chiefly due to a hypoproteinemia. Snell in reporting a large series of cases remarked upon the unusual rapidity with which changes in the total protein value and the albumin globulin ratio could take place and intimated that for this reason repeated observations on the blood protein level might be necessary on the same patient to be of definite prognostic value. Jones and Eaton, in 1933 first called particular attention to the dangers of hypoproteinemia in surgical patients. Following this work, Mecran, Barden, and Ravelin (13) found gastric emptying time to be delayed in hypoproteinemia even in the intact stomach and without any known deficiency of accessory food stuffs. Barden, Thompson, Ravelin, and Frank (2) found the motility of the small bowel reduced during hypoproteinemia and the intestinal motility could be restored to normal, restoring the plasma proteins to normal levels. Thompson, Ravelin, and Frank demonstrated a delay in fibroplasia in the dog in hypoproteinemia and believe that such a deficiency is a factor in the disruption of wounds, and Clark long ago found that wounds healed more rapidly and the lag period was re-

duced when patients were given a high protein diet.

Many attempts have been made to find easily determined measurements of the blood proteins by their physical properties rather than by their chemical analysis. Starlinger and Hartl have reviewed methods based on interferometric, polarimetric, viscosimetric, and refractometric measurements, all of which are influenced chiefly by the proteins among the plasma constituents. The time drop method of Barbour Reiss refractometric procedure and Moore and Van Slyke's (14) gravimetric tests are the only physical measurements which have proved sufficiently practical to win any general use. The refractometric method has been found by Linder Lundsgaard, and Van Slyke (12) to give rather wide errors in normal blood, while Guillaumin, Wahl, and Laurencis found even greater errors in plasma from edematous patients because of the excessive lipid content. The gravimetric method of Moore and Van Slyke the copper sulfate method of Phillips and Van Slyke and the time drop method of Barbour yield equally accurate results when compared with Van Slyke's (11) gasometric micro-Kjeldahl procedure.

Benefits accruing from the intravenous use of erythrocytes, glucose, salt, or Ringer's solution are common knowledge. With the availability of serum proteins and recognition of their value intravenously the problem of choice of the proper intravenous medication becomes both more complicated and more important. A patient's need may become specific for any one or any combination of cells, electrolytes, crystalloids, and proteins, while the cost of serum proteins is high enough to be prohibitive unless they can be proved absolutely necessary.

By the following simple routines we have been estimating the requirements of patients for sugar, salt, fluid, blood proteins, and erythrocytes with reasonable accuracy and intravenous therapy has been more efficiently and economically used by following the results of this laboratory system than when the choice of therapy is left wholly to clinical opinion and judgment.

Fifteen cubic centimeters of blood are taken from the cubital vein of a patient needing intravenous fluid and are placed in a graduated

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centrifuge tube. Coagulation is prevented by the addition of a small amount of heparin being used because any other anticoagulant changes the specific gravity and viscosity of the plasma. At the same time a complete blood count is made from blood taken from the lobe of the ear and a sample of urine is collected. From this time, until the patient is convalescent or no longer needs fluids, each 24 hour sample of urine is saved and a 6 ounce sample preserved. The venous blood is then returned to the laboratory placed in a centrifuge and spun at 2000 revolutions per minute for 10 minutes. At the end of this time the erythrocytes are uniformly packed and the level of erythrocytes is read directly from the graduations on the wall of the centrifuge tube. This hematocrit level read directly gives the percentage of erythrocytes in the circulating blood and by this time the erythrocytes have been counted in the usual counting chambers. If the erythrocyte count is below 3,000,000 or the hematocrit reading below 30 per cent, transfusion of whole blood is advised on the ground that in addition to the clinical indications for fluid erythrocytes are indicated. Furthermore with a hematocrit reading of 30 per cent or less there is a hemodilution and whole blood is needed. The supernatant plasma is now drawn off and albumin globulin ratio is done and the density of the plasma is measured by the falling drop method. At the same time, a qualitative sugar and a quantitative estimation of the chlorides is done on the urine sample. The estimation of sugar in the urine is necessary in order to assure the safety of glucose administration later if indicated. The rationale of the total chloride content of the urine is as follows. In repeated experiments with dogs and on normal as well as ill human beings, we have found that, if 4 grams or more of chloride are spilled over per day in the urine excepting in certain types of kidney disease, the blood chlorides will be at a normal level. Inasmuch as estimation of urine chlorides is simpler, cheaper and faster than the estimation of blood chloride and the sample is much more easily obtained a daily estimation of urine chloride gives one an adequate idea of the circulating chloride electrolytes in the blood. While the first sample of urine taken does not accurately give the 24 hour excretion because the 24 hour sample is available by using 1500 cubic centimeters of urine per 24 hours as a base accurate idea of the chloride excretion of the patient, and of the blood chloride level. Following this sample, the chloride output each 24 hours is estimated from the urine samples saved. With the hematocrit level now available the blood count done the urinary sugar and chloride content estimated the albumin globulin ratio and density of the blood are estimated. From the albumin globulin ratio the total protein of the blood is taken. If the total protein of the blood is below 5 or the albumin globulin ratio is below 1.5 to 1 plasma is indicated, regardless of the need for erythrocytes and can be given of course with or without red cells. The density of the blood is recorded to be used later as a base line in blood protein fluctuations during the ensuing period of illness. Within 40 minutes of the entry of a patient into the hospital on 15 cubic centimeters of blood and one sample of urine and by these four reasonably quick and inexpensive laboratory tests, the ground work has now been laid to indicate the need for erythrocytes, electrolytes and protein. The changing conditions of the patient's circulating tissue can now be followed closely and cheaply by three daily tests. These being the measurement of the density of the plasma by the falling drop method the daily estimation of the urinary chlorides in the urine per 24 hours and a qualitative urinary sugar estimation. As stated previously as long as the daily output of salt is 4 grams per 24 hours it has been our experience that the blood chlorides will remain in the normal zone. Glucose may be given with reasonable safety except perhaps in certain types of liver disease to and past the point where sugar spills over in the urine. But to guard against an excessive administration of glucose the urinary sugar is done and if the urinary sugar remains over +2 for any appreciable period of time, salt or Ringer's solution is advised temporarily to replace the glucose. With reference to the blood protein the albumin globulin ratio and the total proteins are available from the first estimation. At that time the density of the blood was measured and establishes a base line of density against which subsequent 24 hour densities are measured. Almost without exception any rapid drop in the blood density has been in our experience and in the while any rapid rise has been due to an increase in globulin, or a decrease in total circulating blood fluid. An appreciable drop in blood density then in any 24 hour period is taken either to indicate the need for additional albumin as given by blood plasma the existence of a superhydration from excess fluid given by vein, or insufficient fluid elimination by the body. Differentiation between these factors can be done by the clinician with perhaps a hematocrit reading for cell volume. A sudden rise in blood density most commonly oc-

curs from insufficient fluid administration or from a sudden rise in the globulin fraction of the plasma, and in either case water is indicated the crystalloids in the water being determined as stated before, by the amount of chloride and the amount of glucose in the urine. While mistakes may be made in the fluid administration in patients handled in this way they are far fewer than those made in cases in which the plasma is not similarly followed, and while seeming somewhat involved perhaps, the actual costs of the original estimations are reasonable and the follow-up of blood density and urinary chlorides is cheap. Uniform success, of course, is not achieved even when the indications are correct, because in a certain percentage of cases we have found that the administration of plasma when definitely indicated by laboratory methods, still does not cause a beneficial response which one would expect and in a small series of cases in which this has occurred there has been liver damage. On the other hand, the benefit of plasma in far smaller amounts than would raise the blood proteins to a normal level causes an entirely unproportional improvement in the patient's condition. We feel that with blood plasma being now as easily available to the physician and patient as are salt and glucose the methods of control which have been described or similar methods are essential in a proper handling of intravenous therapy.

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EDITORIALS

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OCTOBER 1944

THE ORIGIN OF CHOLECYSTITIS

THE temptation is prevalent to use the words inflammation and infection as synonyms. There is good reason for this. For many years by far the most important cause of such inflammation that has been discussed has been bacterial action. Moreover, our knowledge of bacteria and their effect upon the organism developed almost concomitantly with our knowledge of the cellular response of the organism to injury. Such a subtle association between infection and inflammation has thus suggested that the cause of inflammation first be considered bacterial infection. The frequency in which such has been true has made this approach worthwhile.

As more has been learned about inflammation however and in particular about those substances that provoke inflammation there becomes apparent a large group of diseases affecting the human body in which tissues are damaged without the primary mediation of a

micro-organism. Many of these substances are of endogenous origin and their action may be related to a single organ or to many viscera. Inflammation of the gall bladder seems to offer such a case in point.

It seems to have been almost immediately assumed that inflammation of the gall bladder is due to an infection. This assumption has received corroboration subsequently when the gall bladder has been cultured and organisms have often been found in its wall and in the contained bile. The type of the organisms is variable, belonging most commonly to the streptococcus and colon groups. When it was demonstrated that inflammation of the gall bladder could be produced experimentally by the injection of streptococci into the portal stream the pathogenesis then seemed to be established.

Many phases of the clinical picture of cholecystitis however do not fit in perfectly with such a concept of pathogenesis. For instance, cholecystitis is relatively infrequent in children and its incidence increases very definitely as the individual becomes older. If cholecystitis were entirely bacterial in origin one would anticipate that the reverse would be true. Bacterial invasion of the portal stream is more common in younger individuals, being seen most frequently in association with acute appendicitis, peritonitis, intestinal obstruction and the numerous dysenteries that occur in children. Cholecystitis is more frequent in women and in individuals of certain habitus factors that would seem offhand to have no relationship whatsoever to bacterial invasion. Acute cholecystitis also is almost universally seen in the presence of obstruction of the cystic duct and it has been well recog-

nized for years that inflammation of the gall bladder wall is nearly always associated with cholelithiasis.

One of the earliest observers to call attention to some of the discrepancies mentioned was the late Edmund Andrews, and one of his very important contributions was the culture of the bile and the wall of normal gall bladders the flora being compared with a similar group of acutely diseased and chronically diseased gall bladders. He and Henry were able to demonstrate that both quantitatively and qualitatively there was but little difference in the cultures of gall bladders of all types, including those with acute inflammation and those that were microscopically normal. Often in acute cholecystitis the badly damaged gall bladder wall was found to be sterile as was the contained bile. This has been our experience also. Again often microscopically normal gall bladders would be intensely infested with bacteria of many types in fact with almost any organism that was prone to be present in the intestinal tract of that particular patient. The use of normal gall bladders as a control in studying the bacteriology of cholecystitis was extremely important and strangely enough, had been ignored by previous observers. This failure of correlation between the pathologic changes and the presence of bacteria would seem to raise a very serious factual objection to the age old assumption that cholecystitis is primarily bacterial in origin. It does establish the fact however that often the gall bladder like many other organs in the body is normally a contaminated viscus. This premise being true injury to such a viscus would probably be followed many times by true bacterial infection. Such a conception raises a new problem namely how is this initial injury sustained?

That such a primary injury may be chemical in type has been suggested by several

for example Mann has shown that intravenous injection of Dakin's solution would produce acute cholecystitis. Wolfer has presented evidence that pancreatic juice when introduced into the gall bladder can produce serious destructive changes, as it does in other tissues after it is activated. Andrews and his co-workers have demonstrated that the injection of bile salts into the gall bladder often resulted in acute inflammation.

Because of the very frequent association between obstruction of the cystic duct and acute cholecystitis it occurred to us that the substance obstructed namely bile must play an important part in the production of this inflammation. When one considers the damaging action of bile on tissue when it is placed in the peritoneal cavity in the pancreas or in the subcutaneous tissues, such a conception is a plausible one.

Accordingly we conducted experiments on dogs to demonstrate if possible the damaging action of bile on the gall-bladder wall. It was noted that if complete obstruction of the cystic duct was produced after the gall bladder had been emptied of its bile and the contents replaced with physiologic solution of sodium chloride, there was no evidence subsequently of inflammation in the gall-bladder wall. Hydrops ensued. However when complete obstruction of the cystic duct was performed and bile left imprisoned in the gall bladder the resulting inflammation varied in severity and type in direct proportion to the content and the concentration of the bile obstructed. This inflammation was identical with that encountered in clinical cholecystitis. This damaging action did not seem to depend on any single substance in bile but could be shown to be present when various components of the cholic acid derivatives were used. For the most part, these substances appeared to be cholesterol in its various forms, or some of the

bile salts Of the latter group sodium taurocholate sodium glycocholate and sodium desoxycholate were studied The latter seemed to be the most damaging In cases in which the concentration of bile or of these particular components was one time greater than that normally found in the gall bladder in about half the instances actual necrosis of the gall bladder wall was seen This amount of concentration of bile necessary to produce damage in the gall bladder wall is physiologically possible

Infectious agents in cholecystitis belong to the streptococcus and colon groups of organisms and one would therefore expect a characteristic pyogenic reaction in cases in which infection was predominant This reaction was rarely found to be present A reaction to lipid material on the other hand would consist generally of edema fibroplasia and a histiocytic response as wandering cells xanthoma cells or giant cells Lymphocytes would be present and polymorphonuclear leucocytes rare Exactly this was found

These changes of an acute nature that we have observed with total obstruction of the cystic duct can be correlated with the changes of a chronic nature that Cole and his co-workers have shown to take place with incomplete obstruction of the cystic duct From all of these experimental studies it seemed to us fair to conclude that three important factors were involved in the production of cholecystitis These factors were obstruction of the cystic duct the action of bile on the gall bladder wall and the occasional secondary presence of bacterial infection which would be superimposed upon the chemically damaged tissue Although at times the bacterial infection would often be so great as to overshadow all of the other factors in all probability it is usually preceded by the chemical damage The next problem that asserted itself was to find evidence that human cholecystitis was related to the presence of bile products in the gall bladder wall In view of the fact that most of these chemical irritants in bile with which we are dealing are steroid in type and that such substances often give a characteristic type of inflammatory reaction which is not seen with that produced by bacteria generally found in the gall bladder wall it occurred to us that a more careful study of the cellular reaction in an injured gall bladder should be undertaken The most common in

In a recent study of 354 gall bladders which were removed consecutively in the Barnes Hospital we were able to show that in 36 or 10.2 per cent of our specimens lipid material resembling cholesterol ester was found in histiocytes beneath the mucosa giving the characteristic picture of strawberry gall bladder Such a picture was as a rule not associated with a great amount of tissue damage in the gall bladder wall but was frequently found associated with cholesterol gall stones. In 80 cases or 20.6 per cent of the gall bladders removed there was microscopic evidence of either lipid or bile deep in the gall bladder wall In almost every instance these gall bladders were badly damaged most of them showing evidence of recent acute inflammatory reaction Thus including cholesterolosis or strawberry gall bladder there was a total of 116 cases or 32.8 per cent of the gall bladders removed in which one could demonstrate some histologic evidence of a lipid or bile reaction in the wall of the gall bladder

Such a conception of the etiology of cholecystitis would consider cholesterolosis or strawberry gall bladder an early form of cholecystitis It would not place it in a category apart It would correlate the association of cholecystitis with precipitation of components of bile in the gall bladder to form

stones and the relationship of those stones to inflammation. It would explain why in the gall bladder may be found a varied group of organisms ranging from *Streptococcus hemolyticus* to *Bacillus typhosus* with the identical inflammatory reaction. The type of bacteria present in the gall bladder would depend upon

those present in the intestinal tract of the particular individual while the primary inflammatory process is of different origin. Such a concept of pathogenesis satisfies the question raised earlier concerning the many clinical characteristics found in this disease.

NATHAN A. WOMACK



FREDERIC ATWOOD BESLEY

APRIL 9, 1868—AUGUST 6, 1944

MEMOIRS

FREDERIC ATWOOD BESLEY

THE colorful figure of Fredenc Atwood Besley its lights and shadows is not readily portrayed in a pen picture At best such a portrait can hut recall to hundreds of colleagues and students his lovable social graces and pleasantries his forceful teaching and his accomplishments in the field of surgery

Fred Besley s life and activities were identified with the immediate territory in which he was born Waukegan Illinois 40 miles north of Chicago on April 19 1868 the son of William and Sylvia Jocelyn Besley It was here that he developed his love of the outdoors and of horses which he maintained all of his life After graduating from Northwestern University Medical School in 1894 Besley won the much coveted internship in Cook County Hospital an institution which throughout its history played a dominant rôle in shaping the careers of many prominent men of medicine not only in Chicago hut throughout the nation Here he came under the influence of an attending staff on which were such men as John B Murphy Weller Van Hook Christian Fenger James B Herrick, and other clinicians who were building the reputation of the young medical center of Chicago Leaving the County Hospital, he entered general practice on the South side of Chicago and in 1899 joined the surgical faculty of his alma mater as instructor advancing to the rank of professor in 1915

In 1900 Besley was appointed professor of surgery at the Chicago Post Graduate Medical School and Hospital Here began an intimate friendship and association with Franklin H Martin that was to endure the entire lives of the two men At this time began his close association with Allen B Kanavel and Harry M Richter all three men being strongly influenced by Weller Van Hook chair man of the Division of Surgery at Northwestern until 1909 Then, following through under the leadership of John B Murphy these three men contributed much to the development of the strong Department of Surgery at this institution and to the surgical reputation of Wesley Memorial Hospital at that time where they served as attending surgeons

In 1904 Besley was appointed attending surgeon at Cook County Hospital which position he occupied until America s entry into World War I when he was commissioned Major and Chief Surgeon of Northwestern University Base Hospital No 12 Serving in France he later became Division Surgeon and retired with the rank of Colonel

Returning to practice and teaching in Chicago in 1919 Besley began to feel the lure of the countryside he loved so much as a boy. In 1924 he returned to Waukegan to take up practice there. With his love for organizing he founded the Besley Waukegan Clinic at the Victory Memorial Hospital in which he was active until the time of his death.

A founder member of the American College of Surgeons, Besley served this organization many years as treasurer, president, member of the Board of Regents, and from 1938 as secretary until the time of his death. In 1905 with Franklin Martin, Allen B. Kanavel, John Hollister and William R. Cubbins, he served as founder member on the Editorial Board of SURGERY GYNECOLOGY AND OBSTETRICS and continued actively on that board from the time of its establishment.

In his later years, Besley became interested in traumatic surgery, becoming the first chairman in 1926 of the Committee on Industrial Medicine and Traumatic Surgery of the American College of Surgeons, serving in this capacity until 1939. He was a Fellow of the American Surgical Association and a member of the Chicago Surgical Society.

This, very briefly, is the sketch of a man who throughout his professional life, was continuously active in advancing the frontiers of surgery. His surgical judgment and his operative technique were excellent. He was always gentlemanly and courteous. He loved life and he loved people. A liberal in his thinking, he was easy in his judgments of his fellow men, affable, genial, personally attractive, ever ready with friendly encouragement or witty rejoinder. He died August 16, 1944, at the age of 76.

J. R. BUCHHEIMER

THE SURGEON'S LIBRARY
REVIEWS OF NEW BOOKS

THE publishing of *The Human Eye* by Kronfeld McHugh and Polyak brings before us a beautiful example of a new form of color reproduction printed on transparent sheets. This is the first five color process rotogravure to be produced on an acetate base where every color is a process color involving tone etching. The binding of these transparent sheets is arranged so that two are held together with the two pictures in contact back to back on the inside giving protection against marbling—the pictures being viewed through the material. Turning the pages we observe both sides of a series of gross sections. Superimposing gives the effect of three dimensional translucent model.

The original paintings are the work of Kronfeld McHugh and are based on the work of a long study. Reviews.

The original paintings are the work of Gladys McHugh and are based on anatomical dissection and long study. Beside each picture is a brief paragraph of the volume, an explanatory text in the second part of Dr Peter C. Kromfeld. Accuracy of detail in drawing and text is obvious to careful scrutiny. A third section by Stephen L. Polyak, M.D. sums up the History of Our Knowledge of the Structure and Functions of the Eye. Even if you are not interested in anatomy, you will enjoy looking over the material.

valuable, as are those referring to the very in-
clusive chapter on Nutritional Influences on De-
velopment. The section on dental caries as in the
first edition, is not satisfactory. Those familiar
with caries investigation and accomplishment will
not approve and the average reader and student will
be confused. No phase of congenital malformations
of the face and jaws has been neglected. Focal infec-
tions has been dealt with in a concise manner and
the opinions expressed are acceptable and worthy
of studious consideration. The remaining portion
of the book is devoted to broader integration of
diseases and affections of the maxillofacial tissues
with systemic disease.

Although many subjects are treated
the characteristic coverage
etiology, clinical
treatment

Although many subjects are treated with brevity the characteristic coverage of the subjects includes etiology, clinical findings, histologic picture and treatment. The book is profusely illustrated but these vary in quality and utility. Many histologic reproductions are not well done. The book can be considered as an encyclopedia rather than a text book and is a worthwhile addition to any dental or medical library.

Pharmacia IV Merrick

AFTER carefully studying the first edition of *Textbook of Oral Pathology*, I have found it to be a most valuable addition to the dental library. The book is profusely illustrated but these vary in quality and utility. Many histologic reproductions are not well done. The book can be considered as an encyclopedia rather than a text book and is a worthwhile addition to any dental or medical library.

FREDERICK W. MERRIFIELD

AFTER carefully studying and reviewing the 3d edition of Volumes 1 and 2 of Watson Jones' work, I am of the opinion that these books are the best word on our present treatment of fractures and joint injuries. Additional information has been gleaned from the author's experience in the present war. The illustrations, colored pictures, x rays and end results are really a work of art. This is one of the easiest fracture books that I have seen. The easiest fracture book that it has been my pleasure to read. It is comprehensive and runs pleasantly.

These results are really a work of art. This is one of the easiest fracture books to read that it has been my pleasure to review. It is comprehensive and gives the author's views of all the more common fractures and joint injuries encountered. True there are some forms of treatments suggested that one may disagree with but that is only natural when one covers the subject as Watson Jones has in these volumes. Many sections are superior to the present day orthopedic and fracture references in that a clear explanation and fracture treatment. No one chapter for good bone and joint standing because all of them deserve creditable mention. His conservative views are to be admired and it is my personal opinion that these books are a real contribution to bone and joint surgery. These volumes can be highly recommended for general practitioner and specialist.

JAMES J. CILLIAN

Fractures and joint Injuries. By R. W. (1900-June, D.C. M Ch
Orth. F.R.C.S. (Ed. and 2d ed. Baltimore The Williams &
Wilkins Co., 9 J

44

THE book *Oral Pathology* was originally pre-
sented by Thomas in 1941. The reception of this
excellent work warranted the preparation of the
new second edition. The subject matter does not
differ a great deal from the previous edition but
some new material has been added. The material is
again classified in twelve parts. The material is
material provides for easy reference and each part
follows the other in reasonable sequence. Emphasis
is laid upon the value of experimental pathology and
the graduate student will profit accordingly from
experimental suggestions and guides
The first 758 pages of the book are devoted essen-
tially to the teeth and their supporting tissues but
the chapters on "The Modification of Growth and
Development By Local Factors and Somatic Dis-
ease" and "Maldevelopment of the Face and Jaws
and Malocclusion of the Teeth" are to be especially
mentioned. Hereditary and endocrine influences on the
development of the teeth and jaws are the subjects
of important chapters and the bibliographies are

[illegible]

AMERICAN COLLEGE OF SURGEONS

1944 CLINICAL CONGRESS CANCELLED TO AID WAR EFFORT

THE American College of Surgeons, upon action of its Board of Regents, has cancelled its annual Clinical Congress because of the acute war situation that has developed, involving greater demands than at any time in the past upon our transportation systems for the carrying of wounded military personnel, troops, and war material. The Congress was to have been held in Chicago, October 24 to 27.

Dr Irvin Abell of Louisville, chairman of the Board of Regents, in making the announcement, said that this action was taken after consultation with the officials in Washington. Some of the replies which were received from these officials read in part as follows:

From Major General Norman T. Kirk, Surgeon General, United States Army

"Naturally all like these meetings to be held and to attend them. However from an official standpoint I must say we are needing more and more railroad transportation to move our battle casualties from the ports to our hospitals. And there are still many troops in the United States who require railroad transportation to ports in order to get them overseas. In addition difficulty is being experienced in obtaining the necessary material to continue the battle. This means transportation for the raw materials that go into munitions and the shipping of these munitions to the ports after they are fabricated. Each month the need for the material overseas is increasing rather than diminishing.

"The war is far from over and I think we should all consider the war effort rather than the satisfaction of our individual desires. That should give us the answer. After seeing the bomb craters and destroyed homes, factories, and transportation facilities in Europe, I am not surprised that this nation feels it is far removed from war and that the war is about over. It isn't.

From R. C. Clare, Assistant Director, Passenger Section, Division of Traffic Movement, Office of Defense Transportation

"This office cannot attempt to evaluate the importance or the essentiality of any particular meeting. We have attempted to clearly portray the present critical transportation situation. The transportation requirements of the armed forces are not at present being entirely satisfied. At the same time, soldiers and sailors on leave from duty overseas are unable to secure Pullman accommodations to their homes and frequently have to stand in coaches for considerable distances. The responsibility therefore, rests

upon the officer of your organization to determine if, in the light of these conditions, you should go through with your Chicago meeting.

"I believe you will agree that the Office of Defense Transportation cannot attempt to make this decision for you. We assure you that there is an urgent need for the curtailment of convention travel in order to clear the transportation channels of the country for the movement of military and essential civilian travel. We, therefore, ask for your serious consideration of our appeal in the light of this situation.

Feeling that the many factors in favor of holding the Clinical Congress, however important, are less vital than the assurance of adequate transportation and the best medical care for the wounded, as well as the clearance of transportation facilities so far as possible for the conveying of troops and war material, the American College of Surgeons willingly cancels, for the third successive year, its annual meeting in order to aid the war effort. The Regents recognize that there is a great burden on the members of the surgical profession in their local communities as the result of the large proportion of the profession which is serving with the armed forces. They also take cognizance of the desire of the profession to do nothing which would interfere with the successful prosecution of the war program, such as would be caused by the temporary absence of its members from duties during the period of the Congress. More than three thousand surgeons and some two thousand hospital representatives usually attend the Clinical Congress.

At the annual meeting of the Board of Regents to be held later in the year, fellowship in the College will be conferred *in absentia* on the class of Initiates of 1944. At the same time the list of hospitals, cancer clinics, medical services in industry, hospitals conducting programs of graduate training in surgery and medical motion pictures, that meet the College standards, will be approved and later published. All present officers, regents, governors, and standing committees will continue in office.

War conditions permitting, the Clinical Congress will be held in the fall of 1945.

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TRANSURETHRAL RESECTION AND OPEN PROSTATECTOMY

A Consideration Based on Ten Years of Experience
With Transurethral Resection

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IN articles which have appeared from time to time, the attempt has been made to compare transurethral prostatic resection with suprapubic and perineal prostatectomy. The authors of these articles have tried to present a fair and conscientious analysis of the problem. Unfortunately, however, the deductions that have been drawn require clarification in the minds of physicians throughout the nation. In attempting to evaluate any data on this subject, the discerning investigator will do well to remember that it is erroneous to assume that the results of any type of operation are entirely satisfactory in 100 per cent of cases. This applies to prostatic operations as well as to operations on other parts of the body.

From the experience of the past 10 years in any large medical center it would be possible to collect data on a substantial number of cases, a few hundred perhaps, in which prostatectomy had been performed after transurethral resection had yielded imperfect results or symptoms had recurred. A first impression then would be that the incidence of imperfect results or recurrent symptoms after

transurethral resection is relatively high. When the enormous number of transurethral resections that had been done throughout the nation during this period was considered, however, this figure would be considerably less imposing than at first it had appeared. For instance, at the Mayo Clinic alone during the period of 10 years from 1933 to 1942 inclusive 8,954 transurethral resections were performed in 8,422 cases.

TRANSURETHRAL RESECTION FOLLOWING OPEN PROSTATECTOMY

Before an attempt is made to compare transurethral resection with open prostatectomy, it might give balance to the subject to discuss the incidence of, and the reasons for, poor results and recurring symptoms following open prostatectomy. The incidence is higher than is generally realized (1).

For instance, during the 10 year period (1933 to 1942 inclusive) at the Mayo Clinic transurethral resection was performed on 102 patients on whom suprapubic or perineal prostatectomy had been performed previously, either at the clinic or elsewhere. The tissue removed from 66 of these patients was benign.

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TABLE I.—INTERVAL BETWEEN OPEN PROSTATECTOMY AND SUBSEQUENT TRANSURETHRAL RESECTION

Interval years	Cases in which resection disclosed malignant tissue	Cases in which resection disclosed benign tissue
Less than 1 year	7	8
1 to 3	3	1
3 to 5	5	5
5 to 10	6	7
10 to 15		9
15 to 20	4	4
More than 20	1	8
Total	30	60

while that removed from 36 was malignant. Of the 36 cases in which the tissue was malignant it will be seen (Table I) that in 16 the open prostatectomy had been done more than 10 years before the transurethral resection. It must be assumed, therefore, that the original prostatectomy no doubt had been done for benign prostatic hyperplasia. This would tend to dispel the prevalent idea that so called total prostatectomy necessarily gives protection from subsequent development of a carcinoma of the prostate gland. It also will be noted that in 7 of the 36 cases resection was performed within less than a year after prostatectomy. Fourteen of the 36 patients had suffered from their obstructive symptoms continually since prostatectomy. The immediate results of transurethral resection in these cases were gratifying. Excellent results were secured in 29 cases. The condition of 3 patients was definitely improved, while the results in 2 cases were poor. One patient died after operation and in another case the result was not noted on the record.

In the 66 cases in which the tissue removed at transurethral resection was benign the interval between prostatectomy and subsequent resection varied greatly (Table I). In 31 of these cases, prostatectomy had been done more than 10 years previously. In the majority of the cases, the prostatectomy had been performed by a surgeon who was well trained in prostatic surgery, therefore it must be assumed that the enucleation had satisfactorily approached completeness in most cases. In 20 cases the open prostatectomy had been performed less than 2 years previously while in 8 other cases the interval was larger but the

prostatectomy had been performed less than 5 years previously. In these 28 cases the results of prostatectomy can definitely be classified as unsatisfactory. The most symptom in these 66 cases was recurring urinary obstruction, although hematuria and persistently draining suprapubic sinus were observed in an appreciable number of cases (Table II).

The duration of symptoms following open prostatectomy is recorded in Table III. It is interesting to analyze the reasons for the persistence or recurrence of symptoms after prostatectomy in this group of 66 cases. In 23 of the 66 cases, the pathologic condition found at the vesical neck was postoperative cicatrization or contraction (Table IV). The scar tissue in many of these cases was very dense and firm, and grossly it suggested carcinoma. In the remaining 43 cases, the obstruction was produced by varying amounts of adenomatous tissue. Postoperative scarring of the vesical neck apparently may occur rapidly that is, within just a few months, or it may not become evident for many years. For instance, in 12 of the 23 cases in which postoperative cicatrization or contraction of the vesical neck was found, prostatectomy had been performed more than 10 years previously. The substantial amount of adenomatous tissue removed in cases in which prostatectomy had been performed from only a few months to 5 years previously is proof that adenomatous tissue may be left behind at open prostatectomy as well as at transurethral resection.

The most important consideration, however, is the result obtained with transurethral resection in these 66 cases. In 50 cases, the results were excellent, and in 13 cases the condition of the patients was greatly improved. In

TABLE II.—TRANSURETHRAL RESECTION IN CASES IN WHICH OPEN PROSTATECTOMY HAD BEEN PERFORMED PREVIOUSLY. SYMPTOMS IN CASES IN WHICH RESECTION DISCLOSED BENIGN TISSUE

Symptoms	Cases
Urinary obstruction	5
Urinary obstruction and hematuria	6
Urinary obstruction and incontinence	
Persistent suprapubic sinus	1
Total	60

1 case a poor result was obtained, and in 1 case the patient died after the operation. In 1 case the result was not noted on the record. It can be honestly stated, therefore, that in the great majority of cases in which urinary symptoms occur after open prostatectomy, complete relief can be obtained by a properly executed transurethral resection.

COMPLETE AND INCOMPLETE TRANSURETHRAL RESECTION

The opinion has been expressed by advocates of open prostatectomy that transurethral resection is an incomplete, nonsurgical type of operation. It is further stated that owing to its incompleteness its results are not good particularly that the incidence of recurrent obstruction is too high to justify its being recommended to patients suffering with prostatism.

Any attempt to evaluate accurately the results of any type of prostatic operation in a series of cases is at best discouraging. Interpretation of questionnaires, clinical impressions and prejudice defeat even the most honest medical statistician. For instance, a result classified as good by one physician might be called fair or poor by another. Standards of measurement in judging the results of prostatic surgery are notoriously inaccurate. For this reason I suggest that this evaluation should be made by the patient by his referring physician, by his associates. After all regardless of what physicians honestly believe, in the end patients are the severest critics and stamp methods and results with approval or disapproval.

TABLE III.—DURATION OF SYMPTOMS AFTER OPEN PROSTATECTOMY AND PRIOR TO TRANSURETHRAL RESECTION

Duration of symptoms	Cases in which resection disclosed malignant tumor	Cases in which resection disclosed benign tissue
Not noted in history	1	7
Continuous since previous prostatectomy	14	27
Less than 1 year	8	12
1 to 3 years	5	5
3 to 5 years	5	5
5 to 10 years	3	6
10 to 15 years	1	1
Total	36	66

TABLE IV.—CASES IN WHICH OPEN PROSTATECTOMY HAD BEEN PERFORMED PRIOR TO TRANSURETHRAL RESECTION TYPE OF OBSTRUCTION AT VESICAL NECK IN CASES IN WHICH RESECTION DISCLOSED BENIGN TISSUE

Type of obstruction	Cases
Postoperative cicatrization or contracture	23
Adenomatous tissue	
Up to 5 gm	2
5 to 10 gm	8
10 to 20 gm	19
20 to 50 gm	11
More than 50 gm	3
Total	66

The response of laymen to the operation should be one excellent method of determining if the results are satisfactory. For instance the largest number of open prostatectomies ever done at the Mayo Clinic in any one year was in 1929. In that year the 271 open prostatectomies¹ performed represented only 0.3 per cent of the total clinic registration for that year, whereas in 1942 1,233 patients underwent transurethral prostatic resection which represented 1.4 per cent of the total number of patients registered during that year. These figures should be significant. Not only the number but also the percentage, of clinic patients on whom a prostatic operation has been performed has more than quadrupled and therefore cannot be accounted for by the increase of the general registration. I have looked through many of the records of patients subjected to suprapubic prostatectomy during the 1920's and am unable to see that prostatic operations are being done on slighter indications than formerly. An honest evaluation of the situation must lead to the conclusion that patients are apparently more satisfied with transurethral resection than they were with open prostatectomy. They have talked to their friends who have been cared for by this new procedure, have observed the results, have heard of their experiences in the hospital, have discussed the problem with their family physicians and have elected to have this operation performed.

A brief review of some experiences with transurethral resection at the clinic during the

¹Twenty-eight were perineal prostatectomies and 243 were suprapubic prostatectomies.

past 10 years may help in appraising the status of this operation in relation to other types of prostatic surgery. Before making such an appraisal, however, it should be emphasized that any statistical comparison tends to favor open prostatectomy because we accept patients for transurethral resection who are considered to present too great a risk for prostatectomy and they often are refused open operation. Unless a patient is mentally deranged or moribund we seldom refuse to perform transurethral resection if it is otherwise indicated. In reading the following brief summary of our experience with transurethral resection, therefore, it must be remembered that the experience includes an almost unselected group of patients and a large number of poor risk patients who never would have been accepted for the operation of open prostatectomy.

An excellent opportunity is afforded for study of so called incomplete and so called complete transurethral resections by reviewing our experience at the clinic for the 10 year period 1933 to 1942 inclusive. In 1934, at the clinic, 696 transurethral resections were performed on 630 patients. In no instance was more than 55 grams of tissue removed at one stage and in 87 per cent of the resections, less than 35 grams was removed. Of these 696 resections, 64 (9.1 per cent) were second resections, which were done while the patients were still in the hospital because insufficient tissue had been removed to allow the patient to empty his bladder. These figures can be compared with the year 1942 during which 1,276 resections were performed on 1,233 patients. Of this number of resections only 43 (3.4 per cent) were second resections or planned two-stage procedures, done while the patient was still in the hospital. During 1942 more than 50 grams of tissue was removed (in one stage) in 217 cases and more than 100 grams in 13 cases. The largest amount of tissue removed at one stage during this year was 141 grams. The mortality rate based on patients in 1934 was 0.3 per cent. In 1942 it was 1.1 per cent. An interesting story can be read in the comparison of these 2 years' work. It is evident that many of the resections in the earlier years were incomplete and, from this, it must be expected that some of these patients have re-

quired, or will require, a further prostatic surgical operation. It is remarkable, however, how well the majority of patients have got along with these so called incomplete resections. Possibly it is not justified to ridicule the early statements of the pioneers in resection that only the obstructive portion of the prostate gland need be removed. The immediate results of the early incomplete type of resection were not all that was to be desired, in that pyuria and some frequency and dysuria persisted for some weeks after operation. However, the patients were able to empty their bladders and, in most cases, became almost free of symptoms within 4 to 10 weeks after operation.

A sufficient interval subsequent to that period now has passed that it is possible to begin to evaluate the late results of the so called incomplete resections. It is impossible at this writing to state how many patients on whom transurethral resection has been performed at the clinic have found it necessary to submit to a subsequent prostatic operation. These data can be secured only from a complete follow-up with letters of inquiry. At present such a study is under way and its results will be reported at some future time. It is interesting, however, to note the number of patients who have returned to the clinic requiring a further prostatic operation after a transurethral resection done at the clinic previously. This information is contained in Table V. In this table is shown the number of patients on whom transurethral resection was performed for the first time at the clinic in each year from 1933 to 1942 inclusive. In the adjacent column is listed the number of patients who have returned at any time since the original operation for a subsequent transurethral resection. If one excludes the cases of carcinoma of the prostate (this subject has been reviewed completely by Thompson) it will be noticed that the percentage of recurrent operations since 1935 has been surprisingly low. The percentage is certainly much lower than has been supposed by critics of the operation who suggest that patients must "return every year or so for the removal of a little more tissue."

In evaluating Table V the time interval since the first resection must be taken into

TABLE V—NUMBER OF PATIENTS ON WHOM TRANSURETHRAL PROSTATIC RESECTION WAS PERFORMED FOR THE FIRST TIME AT THE MAYO CLINIC IN EACH YEAR FROM 1933 TO 1942 INCLUSIVE, AND THE NUMBER AND PERCENTAGE OF THESE PATIENTS WHO HAVE RETURNED TO THE CLINIC FOR SUBSEQUENT TRANSURETHRAL RESECTION

Year	Total			Benign			Malignant		
	New patients	Re-turned	Per cent	New patients	Re-turned	Per cent	New patients	Re-turned	Per cent
1933	412	60	16	38	38	14.4	30	4	18
1934	607	60	10.5	537	69	8	70	3	44.3
1935	653	34	8.3	577	4	7	76	13	7
1936	7	30	7	6.3	27	4.3	80	3	5.8
1937	74	30	4	650	3	.0	8	7	20.7
1938	87	5	.0	77		.6		3	9
1939	946	15	3	838		.3	8	5	5.3
1940	97		1.3	863	7	9	9	5	4
1941	945		2.1	843	4	5	13	6	4.6
1942	1,74			1,009			65		
Total	8,004	378	4.7	7,003	38	3.4	1,00	180	4

consideration so that as years pass the percentage of recurrent operations for the various years will vary. However we are now from 6 to 10 years removed from the earlier so called incomplete type of resection of the period from 1933 to 1937 inclusive. Even for this period in only 7.4 per cent of the cases in which the tissue removed at the first transurethral resection was benign did the patient return to the clinic for subsequent resection. If one eliminates the years 1933 and 1934 (which were in reality the first 2 years in which transurethral resection was given serious trial at the clinic) the percentage of subsequent operation on patients whose original operation was done in 1935, 1936 or 1937 has been only 4.4 per cent. In the past few years owing to improved instruments and technique we have been approaching a relatively complete enucleation in a large percentage of our resections so that the patients returning for subsequent resection no doubt will gradually dwindle to an insignificant number. In my opinion however a few patients always will return from time to time as it is practically impossible for even the most experienced surgeon to perform a perfect resection in every case. Judgment is not infallible during operation so that nodules of adenomatous tissue may be overlooked even when a palpating fin-

ger is in the rectum. Technical difficulties occasionally may arise that will require termination of the operation before it is entirely completed. A patient's general condition may be so precarious that a rapid partial operation such as a palliative procedure, is all that is justified. A live patient after an incomplete resection who is able to void reasonably well is preferable to a dead patient after a complete enucleation whether it is done by transurethral or open operation. Moreover patients who have found it necessary to return after 4 to 10 years for another transurethral resection are a satisfied and appreciative group of patients. They regard further transurethral operation as a comparatively minor procedure and accept it without fear or concern.

There is no doubt that the main factor in recurring symptoms is incomplete removal of tissue, but this is by no means the only one. Many patients have enjoyed normal lives, free of urinary symptoms for 10 years or longer and are still free of symptoms after an incomplete resection performed years ago. There seems to be no doubt that so called complete removal of the adenomatous tissue is desirable and guarantees the best immediate and late results. Nevertheless, it should also be appreciated that such a complete enucleation, performed transurethrally, carries more oper-

ative risk than a less thorough operation. The expert resectionist is the surgeon who can perform practically a prostatectomy and yet leave a thin shell of tissue to protect the vascular capsule. This is the most difficult feature of the operation and the one which requires a long period of apprenticeship to secure proficiency.

It is interesting to know why patients return for further resection. For instance in the year 1942 of 1,276 resections performed 58 were done on patients on whom resection had been performed previously at the clinic. In 10 of these cases the prostatic tissue was malignant. In the remaining 48 cases tissue removed at the original and subsequent resections was benign. From a study of these cases it is evident that the outstanding symptoms are hematuria and obstruction. In the 48 cases in which the tissue was benign and the patients returned, 27 patients complained only of symptoms of obstruction, 7 of hematuria only and the remaining 14 of hematuria and symptoms of obstruction. The bleeding in nearly all cases originates in eroded prostatic tissue. In the majority of cases in between episodes of bleeding the patient's urine is clear and his urinary function is normal. Most important for the profession to realize how ever is that these patients who have persistent or recurring symptoms can be relieved of their trouble completely by transurethral resection in a very high percentage of instances. It is not necessary to perform open prostatectomy on them. For example of the 48 patients under discussion 43 were completely relieved of their symptoms, while the condition of the 5 remaining was definitely improved.

THE LARGE PROSTATE GLAND

Before the subject of incomplete resection is left the question of transurethral resection and the large prostate gland needs frank discussion. It has been asserted that the large prostate should not be subjected to this operation because complete removal of tissue can not be secured at one sitting the results are not good and the mortality rate is excessive. When one speaks about a large prostate gland, the discussion is immediately on an inaccurate, unscientific basis. A prostate gland

which seemed large to a surgeon in his early experience of resection might seem later of only moderate size. At the present stage of resection and of the development of resectoscopes, a surgeon who has reasonable experience is able to remove easily and comfortably 100 grams of tissue in an operating period of 45 to 60 minutes, which is generally considered the maximal time a patient should be kept on the operating table. Many surgeons have reported much greater weights of tissue removed nevertheless, it is conservative to state that removal of 100 grams of tissue at one sitting can be expected of transurethral prostatic resection at its present stage of development (3). If it is recalled that only about 7 per cent of enlarged prostate glands weigh more than 100 grams (2) the problem under discussion is further limited. I believe that in the case of prostate glands which weigh more than 100 grams, the critics of resection may have a logical argument which must be given serious consideration. They state that if multiple operations in these cases in which the glands are large are necessary the subsequent loss of blood, morbidity and mortality rate do not give the procedure any preference over open operation and that one might just as well perform suprapubic or perineal enucleation of the adenomatous tissue. It must be admitted that the latter would be an easier procedure as far as the surgeon is concerned.

I have no quarrel with the surgeon who finds it the best procedure to care for 85 per cent of enlarged prostate glands by transurethral resection and 15 per cent by open operation. Various factors, however, should be kept in mind. For instance of the 8,465 transurethral operations¹ performed at the clinic from 1933 to 1942 inclusive the mortality rate among patients from whom more than 70 grams of tissue was removed was 2.6 per cent as compared with a mortality rate of 1.2 per cent for the entire series. This figure may or may not be of statistical importance in such a series but it would tend to suggest that the larger the gland the greater the operative risk. However the mortality rate is still much less than the average mortality rate for the suprapubic

¹An operation consists of one or more resections done during the same admission (within 30 days).

or perineal operation. There is another confusing factor. It is extremely difficult to judge accurately the size of a prostate gland even after the most careful cystoscopic and digital rectal examination. A prostate gland that seems huge often will weigh less than 70 or 80 grams whereas one that appears only moderate in size may weigh several hundred grams. Often this is not realized until after the resection is in progress as the tissue may be located away from the urethra and not in the direction of the rectum. Still another factor enters into the situation. The size of the prostate gland does not necessarily determine the difficulty of the resection. The contour of the adenomatous enlargement is very important as a large gland may often be an extremely easy one to resect, while a smaller one may tax the ability of the resectionist. It is apparent therefore, that if it is desired to select a certain proportion of patients for open prostatectomy the problem is not as simple as it appears.

"TYPES" OF GLANDS

Another matter is in need of explanation. In previous years, during the various stages of development of transurethral resection, men interested in this field have written statements about the types of prostatic lesions that are suitable or not suitable for resection. These statements have only confused members of the medical profession and were merely an expression of the writers' ability at certain stages of their experience. As experience grew however it was realized that there were more and more so called types of prostate glands that could be treated by this method. After an experience in many thousands of cases it is our honest opinion at the clinic that almost any prostate gland can be resected successfully. The question of the very large prostate gland I have already discussed. The presence of prostatic calculi is no contraindication to transurethral resection. They can be removed easily and as completely as necessary to secure a perfectly satisfactory result.

MORTALITY AND MORBIDITY

If one takes into consideration the number of patients who die after preliminary suprapubic drainage as well as those who die after

actual enucleation of the prostate gland, the mortality rate of prostatectomy is fairly substantial. In addition those patients whose renal function never improves sufficiently after suprapubic drainage to allow them to become candidates for prostatectomy must be borne in mind. Patients who would not be acceptable for prostatectomy can be and are submitted to transurethral resection. This must be remembered when prostatectomy and transurethral resection are being compared. Our transurethral resection service at the clinic is comparable to most transurethral resection services at other clinical centers where resection is the operation of choice; thus our service may be taken as an example. For instance, on this service suprapubic drainage is almost never employed. Preoperative preparation when necessary nearly always takes the form of drainage by urethral catheter. Tests of renal function other than determination of the blood urea rarely are found necessary. Long periods of preoperative preparation are unusual. Postoperative hospitalization also has been dramatically reduced by transurethral resection. For instance among the 8,422 patients on whom resection was performed at the clinic from 1933 to 1942 inclusive the average postoperative stay in hospital was only 8.6 days. There has been a radical change in the wards for prostatic cases. Instead of patients lying in bed for weeks, rivaling only the orthopedic wards for length of stay in hospital, the ward for prostatic patients on the transurethral resection service now has a rapid turnover comparable to that of wards serving patients who have undergone minor surgical procedures. Add to this the consistently low mortality rate of resection and it must be admitted that transurethral resection has a great deal to offer; no wonder that laymen are beginning to demand it as the procedure of choice for obstruction at the vesical neck.

My colleagues and I are extremely gratified with the immediate results of transurethral resection. Now that we are doing a more or less complete resection in each case, the postoperative course is usually uneventful. The average postoperative course is approximately one week in the hospital and one week as an out-

patient at the clinic. When the patient is dismissed from the clinic on the twelfth to fourteenth postoperative day his urinary function usually is normal aside from the necessity of passing urine from one to three times a night and aside from the fact that the urine is slightly hazy. We feel certain that these results far surpass those that were obtained in the days when open prostatectomy was the procedure of choice at the clinic.

THE PRESENT AND THE FUTURE

The present status and the immediate future status of the procedure seem obvious. In spite of the fact that transurethral resection is still in its developmental stage it has been accepted wholeheartedly by laymen. They are beginning to demand the procedure and this

demand will grow as the general surgical technique throughout the country improves with increasing experience. The tremendous increase of volume of prostatic surgery is coming principally in the centers where transurethral resection is the procedure of choice. The wise surgeon will still do well to perform the operation which in his hands will give the patient best results, but men of the younger generation who are interested in prostatic surgery should seek to acquire ability in the field of transurethral resection.

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DIFFUSION AND LOCALIZATION OF EXPERIMENTAL INFECTIONS OF THE PERITONEUM

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In a previous communication (5) it was indicated that exudate drawn from mid-peritoneal cavity offered a representative picture of the infectious state throughout the rest of the peritoneum. This observation had been made during a study of peritoneal exudate which was found to have characteristics of diagnostic and prognostic value. No further investigation of the mechanism which rendered the midperitoneum representative was attempted at that time. It was believed however that the implications of the observation were rather significant. There was an implied inference that diffusion of bacteria and a uniform cell response occur in the peritoneal cavity from the onset of a peritoneal infection. There was a further connotation that the infection was distributed fairly uniformly over the peritoneum throughout the course of the disease. These deductions are contrary to existing concepts. The prevailing current view pictures a peritoneal infection as spreading from a focus involving larger and larger areas of the peritoneum with the body trying to hold back the onrushing flood of bacteria. Diffusion of an infectious process throughout the peritoneum is assumed to hold a poor prognosis for the patient. On the other hand retention of the process to a limited area is indicative of recovery. Experiences in surgery of the abdominal cavity where pools of exudate may be discovered amidst relatively normal peritoneum would seem to militate further against acceptance of our deductions. An analysis of the concept of a spreading peritoneal infection pushing against a defense barrier discloses that little or no factual demonstration exists to support it. The view is derived largely from inferences of end results observed at surgical procedures and necropsies. The inadequate study of the subject is due probably to the difficulty in reproducing a progressing inflamma-

tion of the bowel wall that would result in perforation and peritoneal infection. An approach to the problem was made by Bergh, Bowers and Wangenstein who induced perforations at various levels of the gastrointestinal tract. These investigators studied the relation of size location of perforation, presence or absence of food within the bowel to the bacteriologic content of the peritoneal cavity, severity of infection and rate of survival. This interesting study revealed that the local and general defense mechanisms are pitted against variable factors which include the site and size of perforation, duration of its patency, content and character of food and motor activity of the intestinal tract. My coworkers and I reported in a series of investigations the progressive peritoneal changes (11), the systemic effects (10) and the stages (6) of a peritoneal infection. Information obtained from these experiments constitutes the background which aided us in some of the interpretations made in the present study.

The present investigation was undertaken to ascertain the mechanism of diffusion of a peritoneal infection derived from a progressively developing perforating lesion of the gastrointestinal tract. Several possible methods suggested themselves. Ligation of a dog's appendiceal appendage and its circulation without additional treatment did not constitute a satisfactory procedure for this study. The experience of most investigators as well as ours disclosed that a large proportion of the animals so treated circumscribe the lesion without involving the peritoneum in general. Obviously the method as such did not fulfill the requirements of the experiment. Bower, Burns and Mangle by administering castor oil to dogs immediately after or 24 hours following ligation of the appendiceal appendage and its circulation succeeded in producing diffuse peritonitis and death in a very large percentage of the animals. Our investigations resulted in

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TABLE I.—OUTCOME AFTER LIGATION OF APPENDICEAL APPENDAGES AND THEIR BLOOD SUPPLY IODIZED OIL AND AIR WERE INJECTED INTO THE LUMINA OF THE APPENDAGES

No. of animals	Outcome of animals
	killed in 16, 18, and 20 hours, respectively after ligation and killed in 30 and 36 hours, respectively. No peritonitis in section. Appendix disintegrated or perforation had not occurred.
4*	Diffusion between 2 and 24 hours. All died in 30 hours after operation.
	Killed within 8 to 24 hours in all animals. 4 animals killed within 8 hours after peritonitis. 4 animals killed within 10 hours after operation. Animals killed in 26 and 28 hours after peritonitis. One animal killed 4 days after peritonitis.
6	killed in 10, 12, and 14 hours, respectively after ligation and before peritonitis. In 2, appendages were comminuted. One killed in 4 days, in 4 days, in 4 days.
	Diffusion on 3d day, killed on 8th.

*Two of the animals received also castor oil by mouth.

similar findings. A further study of the mechanism indicated that the action of castor oil was due to an increased intestinal motor activity and a greater intraluminal tension on the wall of the bowel. Because of the increased pressure on the gangrenous wall, perforation and disintegration occurred before the body defenses were completely mobilized. The greater death rate among the animals which received castor oil immediately after appendiceal ligation (2) also points to that explanation. In further testing this concept we injected air into the lumen of the appendiceal appendage after ligating it at its base. The mortality of the animals was as great as that with castor oil. On the basis of these findings, we adopted for our investigation the procedure of appendiceal ligation and injection of air into its lumen with or without administration of castor oil.

METHODS AND RESULTS OF INVESTIGATION

The first phase of the investigation was performed on 27 dogs in groups of 3 to 5 animals at a time. The appendiceal appendage with its circulation was ligated through a midline abdominal incision. Radiopaque iodized oil in 1.5 and 2.5 cubic centimeter quantities was introduced into the lumen through the wall of the appendage. The oil served the purpose of outlining the appendage on roentgenograms. By this procedure it was possible to determine the time of perforation and the degree and

character of spread of the infection throughout the peritoneal cavity. In some of the animals 1 cubic centimeter of an 18 hour culture of virulent *Bacillus coli* and in others 2 to 5 cubic centimeters of feces were added to the iodized oil. Before injection of the feces it was strained and suspended in normal salt solution. In 18 of the animals 5 to 20 cubic centimeters of air were injected into the lumen of the appendiceal appendage. Other animals were given in addition 60 cubic centimeters of castor oil by mouth immediately after the operation.

The volume of air injected into the lumen of the appendiceal appendage was limited by the capacity of the organ. More than 20 cubic centimeters of air resulted in leakage through the point of injection. In some of the appendages, leakage reduced the air content to approximately 10 cubic centimeters or less. As a rule there was a tendency for a greater air content to induce a more rapid perforation.

Fluoroscopic observations and roentgenograms were made at regular intervals. The air was found to be retained in the lumen in slightly diminishing volumes for 24 to 36 hours. Correlations were made between the time of disintegration of the wall, the diffusion of the contents and the extent of their spread. Some of the animals died within 47 hours. Other animals were killed at intervals which were correlated to the time of perforation and extent of diffusion. Studies of the exudate were made from several parts of the peritoneal cavity. Smears were obtained from the pelvis, the right and left iliac regions, center of the abdomen, wall of the appendiceal appendage, left right and center of the diaphragmatic regions. Bacteria and cells were counted in 20 ml immersion fields and an average obtained for each of the regions. Those animals that survived for longer periods were killed after the 6th day and similar studies were performed on them.

In 2 animals, all the steps of the operative procedure employed on the other dogs except for ligation of the appendiceal appendage and its circulation were carried out. An animal was killed at 12 hour intervals and studies were made on the peritoneal fluid taken from various parts of the cavity.

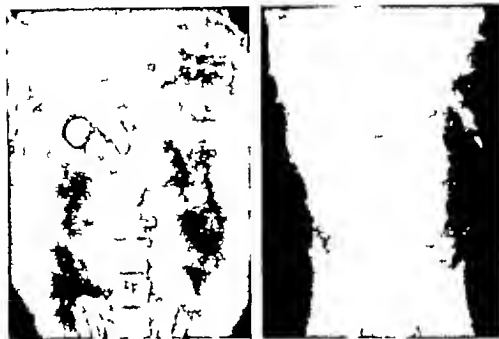


Fig. 1. Rapidity and extent of diffusion of appendiceal contents from a perforated appendiceal appendage in a dog. a, left. The appendiceal appendage and its circulation were ligated and 2.5 cubic centimeters of iodized oil with 5 cubic centimeters of air were injected into the lumen of the appendage. The roentgenogram was taken 2 hours after ligation. The blackened white mass represents iodized oil within the lumen. b, right. This roentgenogram was taken 20 minutes after perforation which occurred 17 hours, 20 minutes after ligation. Note that the iodized oil had completely disappeared from the appendix and diffused fairly evenly throughout the peritoneal cavity. The diffusion extends past the liver.

To determine the effect of iodized oil on bacteria the chemical was added to broth which was then seeded with *Bacillus coli*. In 24 hours the bacterial growth in broth was profuse and equivalent to a broth culture without iodized oil. A culture of a virulent strain of *Bacillus coli* with iodized oil was mixed with gum tragacanth and injected intraperitoneally into a dog. The animal died in 18 hours with a hemorrhagic peritonitis. Apparently iodized oil neither interfered with bacterial multiplication nor reduced the pathogenicity of the *Bacillus coli* strain which was used.

RESULTS OF DIFFUSION EXPERIMENTS

Of 27 animals in this phase of the experiment roentgenologic evidence of perforation appeared in 16. In these animals the iodized oil in the appendiceal lumen was found diminished or absent. In every one of the dogs, the radiopaque substance was visualized in the peritoneal cavity. Whenever the appendiceal appendage became circumscribed after perforation had already occurred some of the io-

dized oil was retained in the lumen. Perforation took place in 18 to 23 hours in 13 dogs. The 14th animal had shown presence of a perforation 2 hours after ligation, the 15th in 26 hours and the 16th in 3 days. Five more animals were killed within a period in which perforation might have occurred. In 6 more dogs the appendix became circumscribed and neither roentgenologic nor anatomic evidences of diffusion were found. Of the 16 animals in which the appendiceal appendage had perforated and diffusion had taken place 4 died. The others were killed. More deaths might have taken place had the dogs been allowed to continue for longer intervals through the course of the infection. The microscopic changes in the exudate suggested that 5 of the 16 animals with perforation and diffusion might have recovered (Table I).

Diffusion of the iodized oil throughout the peritoneal cavity was rapid immediately after perforation (Fig. 1). Within 20 minutes to 2 hours the radiopaque material was seen in the pelvis and around the liver. There was a tend-



FIG. 1. Rapidity and extent of diffusion of appendiceal contents. Circumscription after perforation and diffusion. a, left. The appendiceal appendage and its circulation are ligated and 4 cubic centimeters of iodized oil with 5 cubic centimeters of air are injected into the appendiceal lumen. The roentgenogram was taken 1 hour after ligation. The selected white areas represent the iodized oil within the appendiceal lumen. b, right. This roentgenogram taken 1 hour after perforation. A part of the iodized oil as retained, thus the appendiceal appendage indicating localization after perforation and diffusion had taken place. Not diffusion throughout the peritoneal cavity. 10th accentuation in the lateral gutters.

ence in many of the animals to show greater accumulations of iodized oil along the two lateral gutters. This was true especially in the early stages of the diffusion.

In 2 of the animals a part of the iodized oil was visualized within the appendage. The rest of the radiopaque substance was distributed diffusely through the peritoneal cavity. Examination of these animals showed that the appendiceal appendage became circumscribed after perforation and diffusion of a part of the iodized oil had taken place (Fig. 2).

Fibrin on the surface of the appendiceal appendage appeared early. It was first observed in the animal killed 8 hours after ligation. Irrespective of the condition of the appendage whether perforated or intact circumscribing of the organ continued. Within 36 hours the lesion was usually well circumscribed by loops of bowel mesentery, omentum and parietal peritoneum. In animals without castor oil or air the lesion was found circumscribed and disintegration of the necrotic wall had taken

place apparently within the confines of a sealed area (Fig. 3).

STUDY OF CELLULAR AND BACTERIAL CONTENTS OF PERITONEAL CAVITY

Exudate was obtained before and after perforation of the appendiceal appendages in 27 dogs from 8 areas of the peritoneum: surface of the appendiceal appendage, pelvis, center of abdomen, right and left iliac regions, midperitoneum, right center and left subdiaphragmatic areas. The animals presented gradations of severity of infection. The exudate was collected with a bacteriologic loop and with a cotton swab. Slides were prepared with Wright's and Gram's stains. Data were recorded on the number and variety of bacteria and the number and condition of the cells. Quantitative determinations were made by counting bacteria and cells in 20 oil immersion fields and evaluating the average for one field.

The peritoneal picture was investigated in 8 animals prior to perforation. Studies before

the 16th hour were considered unreliable due to the effects of operation on the peritoneum. Four animals were killed at hourly intervals after the 16th hour. The remaining 3 animals were killed in 24, 30 and 36 hours respectively after ligation.

The studies of the peritoneal reaction prior to perforation of the appendage showed presence of polymorphonuclear leucocytes and desquamated mesothelial cells in every part of the peritoneal cavity under investigation. Polymorphonuclear leucocytes varied in number from 13 per oil immersion field in the 16th hour to 10 in the 24th hour. The average difference in the number of cells in any part of the peritoneal cavity at a given hour did not exceed 16 plus-minus 0.4 per cent. The one exception was the surface of the appendiceal appendage which was covered with fibrin containing enmeshed polymorphonuclear leucocytes. Cells in that location were 6 to 32 per cent greater than in any of the other 7 areas in the peritoneal cavity.

Peritoneal exudate was obtained from the 8 areas at intervals of 4 hours to 3 days after perforation of the appendiceal appendage. The exudate was removed after the animals were killed. The bacterial content in the subdiaphragmatic area and around the appendiceal appendage was found to be greater than in other regions. The relative differences per cent through the various stages of peritonitis



Fig. 1. Appearance of the appendiceal appendage and the peritoneum 24 hours after ligation. The appendage is not perforated. The organ is black but there was no bacterial penetration through the wall. No bacteria were found in the peritoneal cavity. Polymorphonuclear leucocytes were found in every part of the cavity. The entire peritoneum showed hyperemia. The total peritoneum responded to the injury of the appendiceal appendage.

and in infections of variable severity. However, the two areas in which the number of bacteria was greatest did not represent the condition of the peritoneal cavity as a whole nor were they consistent with the outcome of the infection (6 to 11). The bacteria on the surface of the appendage were enmeshed in a fibrin network attached to the wall of the organ. The bacterial content immediately outside the fibrin network corresponded to that of the center of the abdomen.

The leucocyte content in 6 regions exclusive of the appendiceal appendage and the right subdiaphragmatic area showed an average difference of 6 per cent between the lowest and the highest number. The surface of the appendix and the diaphragmatic area contained a very much greater number of cells (Table II and Fig. 4).

In 4 animals killed 4 hours after perforation of the appendiceal appendage, diffusion of bacteria and leucocytes had already taken place throughout the peritoneum. Six of the regions

showed the presence of an average of 5 bacteria. The right subdiaphragmatic area had 31 and the surface of the appendage contained 18 bacteria. While the redized oil could not be seen under the diaphragm in some animals for as long as 16 hours, examination of the exudate showed extension to that area in every one of the animals. It is probable that the inability

TABLE II.—AVERAGE CELLULAR AND BACTERIAL CONTENT IN VARIOUS PARTS OF PERITONEAL CAVITY IN ANIMAL KILLED 26 HOURS AFTER PERFORATION

Area	No. of cells per oil immersion field	No. of bacteria per oil immersion field	No. of cells per oil immersion field	No. of bacteria per oil immersion field
1. Right subdiaphragmatic area	13	1	13	1
2. Left subdiaphragmatic area	10	1	10	1
3. Right iliocecal junction	10	1	10	1
4. Left iliocecal junction	10	1	10	1
5. Right iliocecal junction	10	1	10	1
6. Left iliocecal junction	10	1	10	1
7. Right iliocecal junction	10	1	10	1
8. Left iliocecal junction	10	1	10	1

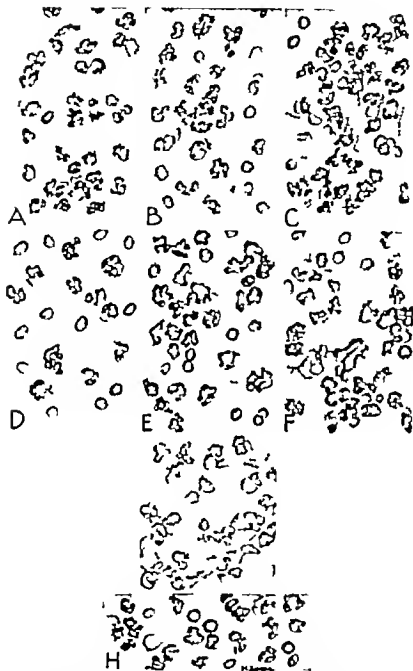


Fig. 4. Stained preparations of the exudate from various regions of the peritoneal cavity of a dog with peritonitis resulting from perforation of the appendiceal appendix. The preparations show leucocytes and bacteria. Observe the relative number of these elements in the following regions: A, left subdiaphragmatic area; B, center of the phrason; C, right subdiaphragmatic region; D, left iliac re-

gion; E, center of abdomen; F, right iliac region; G, surface of the appendiceal appendix; H, pelvic region. Note the close approximation in the numerical content of cells and bacteria in the various regions excepting the surface of the appendiceal appendix and the right subdiaphragmatic region. The last two mentioned areas do not represent the conditions in the rest of the peritoneal cavity.

to visualize the iodized oil was due to technical difficulties. Later improvements of technique allowed visualization of the radiopaque substance under conditions which could not be detected previously.

Those animals which were killed at intervals of 12, 18, 21, 24, 36, 48 and 72 hours after perforation and those which died in 6, 15, 23 and 27 hours after the appendage perforated presented a relatively similar peritoneal picture. Variations in number of bacteria and cells coincided with the stage and the severity of the disease. In the tertiary stage, the number of bacteria in every region approximated that on the surface of the appendiceal appendage. With an increase in content of bacteria the polymorphonuclear cells showed a marked decrease in number.

Localized accumulations of bacteria, cells and debris (abscesses) occurred in the peritoneal cavities of those animals which showed signs of recovery. It is probable that the rapid progress of infection interfered with formation of abscesses in those animals that died. In most of the dogs the general peritoneal cavities containing circumscribed abscesses were free from bacteria. The character of the cellular exudate in the general peritoneal cavity in presence of a completely circumscribed abscess was predominantly mesothelial. Polymorphonuclear leucocytes predominated in the peritoneal exudate when an abscess was poorly or incompletely circumscribed.

DIFFUSION FROM PELVIC CAVITY

The second phase of the investigation was performed on 18 dogs. A mixture of iodized oil, virulent colon bacilli (culture 300) and gum tragacanth was introduced into the pelvic cavity of animals through the abdominal wall with a long trocar. The animals were held in a vertical position during the injection. Twelve of the dogs were placed in a horizontal position 5 minutes after injection and the remaining 6 were held in a vertical position by suspending them in a box. All the animals except 2 were anesthetized with sodium pentobarbital. Two of the animals held in a horizontal position were awake during the experiments. The mixture which was injected into the pelvic cavities varied in quantity. One-

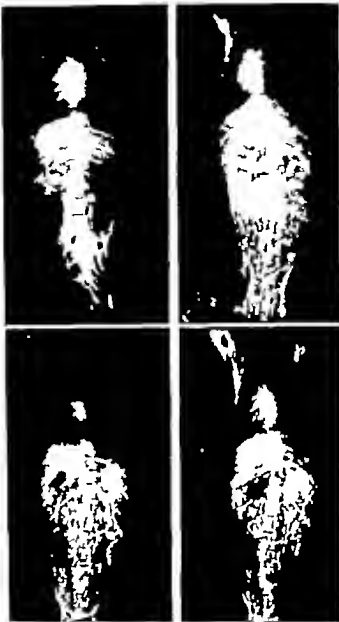


Fig. 5. Rapidity and extent of diffusion from the pelvic cavity. A mixture of iodized oil, bacteria, and gum tragacanth was injected into the pelvic cavity of dogs. The illustrations represent roentgenograms of an animal which was narcotized and held in a horizontal position: a, above left, 1 minute after injection of material into the pelvic cavity; b, above right, 30 minutes after injection. Note the fairly even distribution of the material and height of diffusion; c, below left, 1 hour after injection; d, below right, 3 hours after injection. The material is spread throughout the peritoneal cavity. Observe the gradual decrease in the quantity of the material as a result of its removal from the peritoneal cavity by the defense mechanism.

half of the animals in the two groups (horizontal and vertical positions) were injected with 3 cubic centimeters of a mixture made up of 1 cubic centimeter of iodized oil and 2 cubic centimeters of 1.5 per cent gum tragacanth in physiologic salt solution with 40,000 *Bacillus*

TABLE III.—DIFFUSION OF BACTERIA AND IODIZED OIL FROM PELVIS THROUGHOUT REST OF PERITONEAL CAVITY IN 18 DOGS

Time between injection of material into pelvis and roentgen-ray	Extent and height of diffusion		Quantity of injected material	Posture of animal
	Determined by roentgen-ray	Determined by examination of exudate		
10 min.	Is or is not spread			
	1. Spread uniform and up level of lower pole of kidneys	Same as roentgen-ray	Small	Horizontal
	2. Spread diffuse but more dense in one or both lateral gutters and less dense in crater. Height of diffusion to lower borders of kidneys	Bacteria tend to diffuse more evenly and to margins of kidneys	Large	Horizontal
	3. Spread diffuse but more dense in one or both lateral gutters and less dense in crater. Height of diffusion to lower pole of kidneys	Same as roentgen-ray	Small and large	Upright
	4. Animal with spread evenly and diffusion half way up the liver	Same as roentgen-ray	Small	Horizontal
	5. Pre-existing small amount of peritoneal exudate. Animal asleep spread evenly and half way up the liver	Same as roentgen-ray	Large	Horizontal
1 hour	6. Spread even from crater dorsad but to slight increase in density in one or both lateral gutters. Diffusion extends from level of liver to diaphragm	Same as roentgen-ray	Large	Horizontal
	7. Greater concentrations in crater and left gutter. Half way up to kidneys	Same as roentgen-ray	Small	Upright
	8. Spread diffuse and up level of liver	Same as roentgen-ray	Small	Horizontal and Fowler's
	9. Animal awake spread fairly evenly and close to the upper surface of the liver	Same as roentgen-ray	Small	Horizontal
	10. Pre-existing small amount of peritoneal exudate. Animal asleep spread evenly and reached the diaphragm	Same as roentgen-ray	Small	Horizontal
1 hour	11. Spread even with no or minimal gastric concentration or one or both lateral gutters. Reached the level of the diaphragm	Degree and height of diffusion fairly well correlated	Large	Horizontal
	12. Tendency to concentrate lateral gutters. Reached the level of the liver	Same as roentgen-ray	Small	Fowler's
	13. Spread evenly and reached the upper level of the liver	Same as roentgen-ray	Small	Horizontal and Fowler's

TABLE III.—DIFFUSION OF BACTERIA AND IODIZED OIL FROM PELVIS THROUGHOUT REST OF PERITONEAL CAVITY IN 18 DOGS—Continued

Time between injection of material into pelvis and roentgen-ray	Extent and height of diffusion		Quantity of injected material	Posture of animal
	Determined by roentgen ray	Determined by examination of exudate		
1 hour	Animal awake spread evenly and reached the diaphragm	Same as roentgen ray	Small	Horizontal
1 hour	Tendency to concentrate or lateral gutters prominent. Reached half way up to liver. In 1 hour more even diffusion and up to the diaphragm	Degree and height of diffusion fairly well correlated	Large	Fowler's
	Spread evenly. Reached the diaphragm. In 1 hour, no evidence by ray or microscope of exudate or presence of any material or more in stomach. In 1 hour post tendency persists	Same as roentgen ray	Small	Horizontal

coli. The other half of the dogs received a larger quantity of 15 cubic centimeters. The mixture consisted of 5 cubic centimeters of iodized oil and 10 cubic centimeters of a 15 per cent gum tragacanth in physiologic salt solution with two billion *Bacillus coli*. In 4 animals 1 from each group a peritoneal exudate was induced by intraperitoneal injection of 10 cubic centimeters of coli-bactrogen 24 hours before injection of the iodized oil mixture.

Fluoroscopic observations were made at frequent intervals and roentgenograms were taken at following periods after injections: 1 5 10 30 and 45 minutes; 1 2 2½ 3 4 5 7 9 12 15 18 19 21 22 24 26 28 32 36 42 48 hours. At intervals of 10 30 and 45 minutes 1 2 4 24 hours following injections an animal was killed, and the exudate from various parts of the peritoneal cavity was examined and correlated with the degree of diffusion of the iodized oil.

The purpose of this phase of the investigation was to study the pattern of diffusion from one area in the peritoneal cavity without undue interference from the protective mechanism of the body which exists in a slowly perforating lesion of bowel. This experiment also

offered the opportunity to examine again but under different conditions the extent to which bacterial diffusion coincided with that of iodized oil

The results of this phase of the investigation indicated that diffusion from the pelvic cavity occurred fairly promptly. Within 1 to 2 hours the injected material was found in every part of the peritoneal cavity. The rapidity of diffusion was either delayed or accelerated to a slight degree by varying the posture of the animal and the quantity of injected material. The variations in diffusion were more pronounced when the respiratory rate was altered or when an exudate was present at the time of injection (Table III).

Spread of bacteria and iodized oil tended to become more uniform after the first hour. Animals held in Fowler's posture revealed a distinct tendency for greater accumulation of the injected material along the lateral gutters. Diffusion was consistently more uniform throughout the peritoneal cavity in the presence of an exudate when the volume of the injected material was small and when the respiratory rate and depth were normal or increased. The spread of bacteria followed fairly closely that of iodized oil (Table III).

In the narcotized or anesthetized animals the rapidity of diffusion was diminished. The probable explanation lies in the decrease of rate and depth of respiration and a consequent diminution in the upward suction of the diaphragm. There was a tendency to a slightly greater rapidity of diffusion and a more even distribution with small quantities of injected material than with larger amounts. Presence of fluid in the peritoneal cavity resulted in a fairly rapid and even spread of bacteria and iodized oil. The material in presence of fluid, was carried to the inferior borders of the diaphragm within 30 minutes after the injection.

ANALYSIS OF STUDY

Treatment of peritonitis has been under the influence of the concept that diffusion of an infection within the peritoneal cavity is inimical to recovery. As a result every effort has been directed to delimit and circumscribe the infectious process. Experiences in the management of surface infections and those

in other parts of the body seemed to substantiate the concept as applied to the peritoneal cavity. Since a circumscribed infection is associated so frequently with survival and diffusion with death the mechanism was assumed as obvious. It was overlooked that these processes are end results. It is unfortunate that in human medicine our concepts must be molded so often by observations of terminal changes. In such instances clarification of the mechanism of a disease entity is frequently accomplished by animal experimentation. When the pattern is formed relative clinical observations assume a new significance and fill in the gaps in the pattern.

Under the conditions of our experiments diffusion of an infection has been found to take place in the peritoneal cavity fairly rapidly. Modifying conditions accelerated or delayed the spread of the process, but at no time sufficiently to alter the basic effect. Diffusion of bacteria began as soon as the gastrointestinal lesion had perforated and the micro-organisms were released. In the light of previous observations the purposes of such diffusion can be understood. It had been noted that recovery from peritonitis was associated with a rapid disappearance of bacteria from the peritoneal cavity (7-11). Our investigations (10) had also indicated that the cause of death in peritonitis was due to production of toxic substances by bacteria in the peritoneal cavity. Obviously removal of the micro-organisms prevents elaboration of such toxins. Removal of bacteria is accomplished by two processes: phagocytosis by polymorphonuclear leucocytes and by passage through lymphatic channels and capillary vessels. The advantages of a large peritoneal surface achieved by diffusion of bacteria are threefold: (1) The micro-organisms are distributed in smaller numbers and consequently there is a more efficient and speedier phagocytosis; (2) a greater number of phagocytic leucocytes are able to migrate into the peritoneal cavity and probably at an accelerated tempo; (3) passage of a large number of bacteria through the lymphatic and capillary vessels is made possible. Conversely if the peritoneal area of infection were delimited early in the disease removal of bacteria would be diminished and an in

crease in their number and production of soluble toxic substances would result.

Our experiments showed that in a surviving animal, bacteria which has been diffused throughout the peritoneal cavity begin to decrease in number and eventually disappear entirely. On the other hand in a fatal outcome bacteria appear in progressively larger numbers. On the basis of our investigations as well as of other workers (1) 2 factors may be accepted as deciding the outcome of a peritoneal infection: (1) presence in the peritoneal cavity of environmental conditions which delay bacterial removal or increase the rapidity of bacterial multiplication; (2) an extensive initial or a continued outpouring of bacteria.

In the light of these findings and interpretations the designation spreading peritonitis to denote an unfavorable progression does not characterize the actual mechanism. The term diffuse is less objectionable since it is descriptive of the condition although it fails to differentiate. The infectious process diffuses and spreads from the very onset regardless of the outcome. As a matter of fact, it would be more appropriate to refer to peritonitis either as "regressing or progressing" to denote either a favorable or an adverse course of the infection.

Passage of micro-organisms into the blood stream necessarily produces a bacteremia, which is transient because the bacteria are deposited eventually in the various viscera for disposal by the reticuloendothelial system. That bacteremia is considerably more innocuous than is the persistence of bacteria in tissues has been repeatedly affirmed (4, 5, 9). Goldblatt and I (9) concluded on the basis of our experiments that bacteremia in peritonitis was associated with survival while retention of the micro-organisms in the peritoneal cavity was followed by death.

The belief that localization and diffusion are interlocking and interdependent processes constitutes a part of the current conception. From the point of view of outcome of a peritoneal infection it is necessary to differentiate between localization of a perforating or disintegrating wall of an organ and of pools of exudate. Whenever the latter is an end-result

of a healing process, the rest of the peritoneal cavity is free from infection and shows little or no inflammation. It is highly questionable whether circumscribing of such a process is desirable and favorable to the individual. One may also question whether some of our current methods of treatment do not contribute to formation of these abscesses. Instead of utilizing the large expanse of the peritoneum with its multiple capacities for removal of the elements which form an abscess, we have a small delimited area with most of the functions for disposal of bacteria and debris partly or completely abolished. In addition the abscess becomes a potential source of infection which again endangers the whole peritoneum.

Circumscribing of a lesion present in the wall of the gastrointestinal tract begins immediately after the onset of the process and progresses until the disintegrating wall is reinforced or the perforation is circumscribed. The common observation of the pancreas or a loop of bowel forming a new wall of a perforating peptic ulcer or omentum and intestine circumscribing a ruptured or gangrenous appendix are examples. The reinforcement or circumscription are efforts to seal a focus from which bacteria enter the peritoneal cavity. These efforts may succeed before any micro-organisms escape and peritonitis is prevented or diffusion of bacteria may take place and repair occurs later. If the peritoneal environmental conditions or the massiveness of bacterial outpouring results in a rapidly progressive peritonitis the repair of the lesion is delayed and death may take place before the process is repaired or circumscribed. Recapitulation of these phases of the struggle against a peritoneal infection shows the relationship that localization bears to diffusion.

The observation in these experiments that bacteria and leucocytes accumulate in the right subdiaphragmatic region in greater numbers than elsewhere in the peritoneal cavity is interesting from the viewpoint of formation of a subphrenic abscess. Changes in posture did not appear to alter appreciably such tendencies. The suction action of the diaphragm and the anatomic passageway formed by the right lateral gutter may account for the greater ac-

accumulation of bacteria and leucocytes in that region. Massive bacterial invasion of the area with a resultant vascular stasis and closure by inflammation of capillary and lymphatic vessels by which micro-organisms are removed probably complete the process by which a subphrenic abscess is formed.

In a previous communication (8) the use of peritoneal fluid and exudate for diagnosis and prognosis of peritoneal conditions was described. The criteria for recognition of the various peritoneal infections and irritations were outlined. Since the publication of this article two groups of workers have acquiesced in the value of the procedure. Henry and Vale of Wayne University and Detroit Receiving Hospital, employed the abdominal puncture in approximately 100 patients a year and were able to determine the presence of hemorrhage and infection in the peritoneal cavity. Vaccaro, Parades and Iluc of University of Chile studied the peritoneal exudate obtained by abdominal puncture at operation and from drainage tubes. The authors conclude that the microscopic examination of the exudate offers a simple and valuable method for diagnosis and prognosis of peritoneal infections. Vaccaro and his associates as well as other investigators correlated the outcome of the patient with the species of bacteria found in the peritoneal exudate. There is a general agreement that the presence of certain micro-organisms is associated with a less favorable prognosis. However microscopic examination of a smear of the peritoneal exudate indicates not only the virulence of the micro-organism but also the degree of protection offered by the body defenses (8). Obviously a smear cannot establish the identity of the bacterium, but it has the virtue of supplying considerable pertinent information in a very short period of time.

In our clinical studies we observed that an abdominal puncture in the midline between the umbilicus and the symphysis pubis gave a representative picture of the peritoneal condition. Several reviewers questioned whether information obtained from the exudate in one area portrayed the situation in other parts of the peritoneal cavity. The results of the present experiments offer an explanation of our

previous finding. Bacteria were found to diffuse in fairly equal numbers throughout the peritoneal cavity with the exception of two areas: the right subdiaphragmatic region and the surface of the perforating organ. The distribution of leucocytes followed that of bacteria. It was noted that the spread of bacteria and leucocytes was apt to be more uniform when the animal was not under narcosis or anesthesia and when its posture was horizontal. Other factors which contributed to a uniform diffusion were the presence of a small quantity of exudate and a pre-existing peritoneal fluid. The tendency for greater accumulation in the two lateral gutters and occasionally in the center of the abdomen did not affect the criteria and the information derived from them regarding the general peritoneal cavity.

The reason some workers failed to obtain a satisfactory correlation between the peritoneal exudate and the diagnosis and prognosis of a peritoneal condition was that the exudate was procured from the surface of the involved area of an organ.

SUMMARY

- 1 Under the conditions of our investigations it has been found that a peritoneal infection diffuses throughout the peritoneal cavity fairly promptly after perforation of the bowel takes place.

- 2 The spread of the infectious process is fairly uniform throughout the peritoneal cavity except to 2 regions: the surface of perforated bowel and right subdiaphragmatic area.

- 3 The cytologic response to the infection follows that of bacterial spread. The number of cells is fairly uniform throughout the peritoneal cavity with the exception of the surface of the perforating area of bowel and the right subdiaphragmatic region.

- 4 On the basis of previous investigations and of those reported in this presentation it is believed that the right subdiaphragmatic region and the area of the perforated bowel do not represent the condition that exists in the general peritoneal cavity.

- 5 On the other hand exudate obtained from other regions of the peritoneum including the midabdomen is representative of the

degree of infection and the state of body defense of the entire peritoneal cavity

6 The diffuse peritoneal involvement which takes place shortly after perforation of the bowel is not inimical to the body. It is, as a matter of fact, essential to the defense mechanism. It provides an extensive surface from which (a) bacteria are removed from the peritoneal cavity (b) a greater number of leucocytes migrate to the peritoneum, and (c) phagocytosis is more effective since bacteria are distributed over a wide area and leucocytes are confronted by relatively few microorganisms

7 Under the conditions of our experiments we found the present concept of a spreading peritoneal infection with diffusion considered as inimical to recovery to be erroneous.

8. Terms, "regressing and progressing peritonitis" are suggested as indicative respectively of recovery and of adverse outcome instead of the current terminology of "diffuse and spreading" peritonitis.

9. An approximate period of 36 hours is required for the body defense to reinforce the disintegrating wall of a dog's gangrenous appendiceal appendage and prevent perforation into the peritoneal cavity and development of peritonitis.

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THE THERAPY OF BURNS

A Comparative Experimental Study Including a Medicated Pliable Gelatin Film, and a Note on the Effect of Firm Dressings on the Rate of Healing

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THIS study was undertaken to determine (a) whether a medicated pliable gelatin film possesses any advantages in the treatment of burns other than the ease of application and (b) whether the film disturbs or promotes the healing of burns.

METHODS

Preparation used The protein film (sulfagel¹) used was supplied by Lloyd A. Hall of the Griffith Laboratories of Chicago. It consists of a pliable sheet of gelatin (nonallergic) containing 2.5 per cent sulfathiazole, some potassium iodide (20 per cent) and enough glycerine and water to render it soft and pliable. For comparative controls three other preparations were used. One consisted of a 2.5 per cent sulfathiazole ointment, the base of which was glycerol monostearate. It was used as a control for the 2.5 per cent sulfathiazole in the gelatin film. It was applied by spreading thickly on a piece of gauze and without a pressure dressing. The second consisted of Pickrell's solution consisting of sulfadiazine (3 per cent), methocel (3 per cent), triethanolamine (8 per cent), sorbital (4 per cent), sodium benzoate (0.1 per cent) and water (81.9 per cent). As will be indicated later the sulfagel was applied by 2 different methods. The third consisted of 10 per cent boric acid ointment (U.S.P.) spread on gauze and applied as a firm pressure dressing.

The animals used were dogs because a standard or controlled third degree burn could be produced under anesthesia on each side of the back, and one preparation could be compared with another on the same animal.

Observations were made on (a) the extent of the enlargement of the primary wound after

its infliction, (b) the presence or absence of infection as indicated by the presence of pus, (c) the time required for covering the defect with epithelium and (d) the extent of the scar tissue formed.

The types of wounds studied were

The excoriation wound Such a wound was made to ascertain if the sulfagel film as compared to sulfathiazole ointment, containing the same amount of sulfathiazole as the film, delayed the regeneration of epithelium and hair growth.

Ten dogs were anesthetized, their backs were shaved and cleansed with soap and alcohol. An excoriation wound was then produced on both sides of the back after the method of Thiersch the skin being removed down to the base of the hair follicles. The wound on the left side was treated daily with the sulfathiazole ointment *without pressure dressing* and the wound on the right side was treated daily with the sulfagel film *without pressure*.

The excision wound The excision wound was made for the purpose of comparing the rate of healing of such a wound—not exposed to heat—with that of a wound produced by heat or a third degree burn *destroying all layers of the skin*. The wound was made by anesthetizing the dog, shaving the skin of the back, and then excising with aseptic procedure all layers of the skin in an area on each side of the back. The aim was to excise about 20.5 square centimeters of skin so that the resulting wound when the surrounding skin retracted measured about 50 square centimeters in area. (The actual amount of skin removed is shown in Table I.) The wound on the left side was treated daily with the sulfathiazole ointment *dressing without pressure*. The wound on the right side was treated daily with the sulfagel film *without pressure*. Eight dogs were used.

¹From the Department of Physiology, Northwestern University Medical School.

TABLE I.—EXPERIMENT B EXCISION WOUNDS

Dog No.	Area of scar removed sq. in.		Days of infection		Days required for complete regeneration		Size of scar % of total wounds operative and healed	
	Left	Right	Left	Right	Left	Right	Left (un-circled)	Right (un-circled)
		14	8			47	32	26
3	14	42	12		30	30	6	80
3	30	3 56	16	3	47	32	36	
	20	86	19	3	32	34	62	80
	43	3 97	14	14	97	96	27	66
6	97	87	20	6	96	96	70	87
7	14	3 97		6	30	30	48	6
8		20	16				96	6
Avg.	3 19	3 16	6	4 6	32 3	32 3	31	73

Left side—sulfathiazole ointment treated wounds

Right side—sulfagel treated wounds

The burn wound The burn wound was made by anesthetizing the dog by shaving the skin of the back, and then by burning with a rectangular shaped iron measuring 21.4 square centimeters in area (5.1 by 4.2 cm). This iron was heated in a furnace at 150 degrees C for 30 minutes. It was then applied to the skin for 30 seconds. This destroyed all layers of the skin in an area of about 4 square inches or 26 square centimeters. The eschar was not removed but was permitted to come away of its own accord. The method of dressing the burn wounds will be given later under the appropriate topics.

In all cases the dressings were covered by a loosely fitting apron bandage to prevent injury to the wound by scratching and to keep the underlying dressing clean.

Histological examination After complete epithelialization of the wound had occurred the scar was removed and examined histologically (hematoxylin and eosin, van Gieson and Mallory stains) with the idea of ascertaining the amount of scar formation. This was roughly estimated by measuring the average thickness of the scar and multiplying by the area of the scar. Such results simply verify the visual impression one gains from a study of the sections.

Measurement of the wound The size of the wound was followed by placing a sheet of

cellophane over it, outlining the wound and then determining the area with a planimeter (7). Colored photographs of the wound were made weekly in certain dogs. In making the tracings and photographs the animals stood in a stock, to which they had been trained this rendered the size of the wounds constant and avoided the errors in measurement referred to by Carrel.

RESULTS

Experiment A Excoriation wounds The excoriation wounds made in the 10 dogs (total of 20 such wounds) measured in area from 12.4 to 15.5 square centimeters. The average size of the wounds on the left side treated with the sulfathiazole ointment was 13.7 square centimeters and on the right side treated with the sulfagel film was 13.8 square centimeters. The wounds on the left side healed in an average of 11.5 days and on the right side in 11.2 days. One of the wounds treated with the ointment was infected; it healed in 17 days, a small scar with incomplete hair growth resulting.

The hair growth from the two differently treated wounds was compared and no difference was found. The regeneration of hair follicles was complete, according to counts and observations on the rate of growth of hair made by comparing the area excoriated with a nonexcoriated area after the two areas had been shaved several weeks after the excoriated wound had healed.

Comment No evidence was obtained in this experiment showing that the ingredients of the sulfagel film or of the 2.5 per cent sulfathiazole ointment were toxic to regenerating epithelial cells.

Experiment B Excision wounds The wounds not being supported by a pressure dressing enlarged considerably. Small areas of infection were present in the wounds treated with the 2.5 per cent sulfathiazole ointment. The average days of some infection in the wounds treated with the ointment was 16 days and with the film 4.6 days. However both wounds on the average healed in approximately the same time, namely 32.5 and 33.3 days (Table I). The scars were uniformly larger (Table I and VI) than the original area of skin excised.

Comment The only advantage that the sulfagel film had over the ointment was in regard to the decreased presence of areas of infection and less enlargement of the primary wound. It is of interest to note that the healing time was the same regardless of the presence or absence of the infection which was not however extensive. The sulfagel film was apparently more impervious to the passage of bacteria than the gauze ointment dressing. Histologically there was no definite difference between the scars (Table VI). The scars were larger than the originally excised skin probably because of the lack of support of the skin edges due to the absence of a pressure or retaining bandage.

Experiment C Burn wound treated with sulfagel and sulfathiazole ointment In this experiment a loose dressing was used and the edges of the wound were not supported with adhesive tape. The eschar was not removed by us at any time it came away with the change in dressings. The sulfathiazole ointment softened the eschar and caused it to come away early this permitted the wound to undergo more enlargement than occurred with the sulfagel film. Again the incidence of small areas of infection was greater with the sulfagel ointment than with the film. The wound treated with the film healed more rapidly on the average but the difference in rate of healing was not statistically significant, i.e. the difference observed could have been due to chance variation. The size of the scars was not significantly different though the average thickness was greater for the sulfagel ointment this was due chiefly to one specimen we doubt the significance of the greater average amount of scar tissue.

The essential data are shown in Table II. It is to be noted that 11 of the 19 animals died during the course of this experiment from respiratory disease. The respiratory disease delayed healing. It might be stated that the burns decreased the appetite of all the dogs during the first 3 to 7 days which was not true of the excision wounds.

Comment Though the average results indicate that the sulfagel film is superior to the ointment in all regards the only definite advantage is that it prevented some of the en-

TABLE II.—EXPERIMENT C SULFATHIAZOLE OINTMENT COMPARED WITH SULFAGEL

Dog No.	Per cent maximum enlargement of wound		Days of infection		Days required for complete regeneration		Size of scar as diff. wounds operative and healed	
	Left	Right	Left	Right	Left	Right	Left	Right
1	5	26.5	17		5	45	5 DI	5 DI
4	240	33	4	7	64	35	44 D	1 DI
8	30	145		14	4	40	40 I	35 DI
12	80	30	18	14	35	34	7 D	5 I
	430	300	6	6	37	36	26 DI	13 DI
3	335	47.5	5	0	33	45	5 DI	8 DI
5	5	160			70	68	D	DI
18	87	7.5			6	45	10 D	5 DI
Ave	207	6	13	6	34	43.0	9 DI	4 DI
"Dogs which died during the experiment"					Days lived		% regeneration	
	31.5	68	0		0	- 30	- 5	
3	24	30	5		5	- 7.5	- 70	
5	87	33.5	0		7	- 65	- 5.5	
6	70	7.5			4	- 70	- 27.5	
7	37.5	7.5			6	- 27.5	- 7.5	
9	93	35			7	- 95	- 35	
	0	7.5	5		5	- 0	- 7.5	
4	405	35	3	0	30	- 85	- 4.5	
6	30	30		3	7	+ 4.5	+ 0.5	
7	410	70	5		30	- 40	40	
9	87	5	0		30	15	77.5	
Ave	5	5	6.6	0	9.3	- 58.6	- 5.0	

Left side—ointment treated wounds
Right side—sulfagel treated wounds

"D" decrease
"I" increase

largement of the wound by serving as a partial support or a sort of court plaster. The greater average healing time for the ointment was probably due to the greater initial enlargement of the wound.

Experiment D Burn wound treated with sulfagel and Pickrell's solution This experiment was performed because Pickrell's solution produces a film though it is not as readily applied as the sulfagel film.

The Pickrell's solution was applied by spraying the wound every 2 to 4 hours until a definite film was formed over the burned and surrounding surface. The film was allowed to remain until it came off with the dressing then a new coat of the film was applied. Any cracks in the film were covered with the solu-

tion. This was repeated as frequently as necessary. The coated wound was kept covered with gauze supported by adhesive tape and the additional protective bandage referred to under "methods." The dressing was held firmly by the adhesive tape.

The method of applying the sulfagel film was modified in this and the next experiment. The method was changed (a) to prevent the first twinge of pain which occurred when the sheet of film was applied and (b) to introduce the principle of a firmer pressure dressing.

A portion of the original gelatin film was melted by placing it in a sterile vessel left in hot water. The melted film was then applied to the wound and as it solidified the wound was covered with a patch of the unmelted film. The unmelted film was then covered with gauze and held in place firmly with adhesive tape. This dressing definitely increased the court plaster effect of the sulfagel film. This step was thought to be necessary in order to make a fair comparison with the film made by the Pickrell's solution.

The essential data are shown in Table III. It is to be noted that the wound treated by the new method of applying the sulfagel film decidedly reduced the initial enlargement of the wound. The film formed by Pickrell's solution was about as effective in this respect as the old method for applying the sulfagel film (see Table VI). The Pickrell film tended to break especially at the line between

the eschar and unburned portion of the skin which permitted enlargement but not as much as when the sulfa ointment was applied with a loose dressing. The wounds treated with Pickrell's solution did not heal as quickly and were not as free from infection as the wounds treated with the sulfagel film applied by the new method. The scars formed after the use of Pickrell's solution were smaller but the histological sections failed to reveal that the scars were definitely thicker though on the average they were slightly thicker.

Experiment E. Burn wound treated with sulfagel and boric ointment with pressure. The sulfagel was applied as described in the previous group of experiments. The boric acid ointment (U.S.P.) generously applied to gauze was placed on the wound. This was covered with a layer of gauze and firmly held in place with adhesive tape as described.

The essential results are shown in Table IV. The results with the sulfagel film practically duplicate the results obtained in the previous experiment. The healing time with sulfagel and boric ointment was approximately the same. The incidence of areas of infection was greater in the case of the ointment but the area of the scar was less (Table VI).

Comment. In general no striking difference was obtained between the end-results of the sulfagel therapy with a firm dressing and of the boric ointment therapy with a firm dressing. The ointment however by increasing the rate of softening of the eschar caused a greater initial enlargement of the wound and for some reason caused an earlier contracture of the scar.

Experiment F. Comparison of the "old" and "new" method of applying sulfagel. In the old method, a sheet of sulfagel film was simply placed in contact with the burned area with 2 centimeters or more of overlap of the unburned area. In the new method some of the sulfagel film was melted and poured over the burned area which was then covered with a sheet of the unmelted film after which a firm dressing was applied. This method abolished the twinge of pain associated with the direct application of the sheet of film.

The data resulting from the use of the two methods are shown in Table V. It will be

TABLE III—EXPERIMENT D "SULFAGEL COMPARED WITH PICKRELL'S SOLUTION"

Day No.	Size of original wound sq. in.		% maximum sloughing		Days of infection		Days of healing		% d.s. wounds operative and healed	
	sq.	in.	Left	Right	sq.	in.	Left	Right	Left	Right
1	6	6	107	5			43		77	D
2	6	6	87	2	36		36	44	1	D
3	6	6	43	2	17	3	32	40	1	D
4	6	6	42	2	30	6	43		1	D
5	6	6	17	3	104	3	31	36	1	D
Average	4	4	5	2	36	6	32	37	6	1.08

Left side—sulfagel treated wounds by the "new" method.
Right side—Pickrell's solution treated wounds.

D = decrease in size.

noted that only 1 of the 10 dogs treated by the new method developed small areas of infection in the wound as compared to 5 of 8 dogs treated by the old method. The definite difference between the rate of healing is also to be observed as well as the degree of initial enlargement of the wound. This however is most logically attributed to the firmness of application of the dressing

EVALUATION OF STUDY

Did the infection observed in the wounds delay healing? When this work was initiated it was believed that infection would delay healing and hence care was exercised to prevent infection. In this regard we were successful, since the wounds of none of the dogs became markedly infected, as judged from the amount of exudate and the extent of the area involved. As stated before, the areas which were overtly infected were small in area. Carrel and Hartman (7) found that the presence of infection for a period had no marked effect on the total healing time. The infection they observed temporarily delayed healing but the subsequent increase in cicatrization compensated for the delay.

To make certain whether the extent of infection which did occur influenced healing appreciably, the time of healing of the wounds noninfected for a period of 3 days or longer was averaged the same being done for the infected. The average time of healing of the wounds which showed some infection for 3 days or more (29 such wounds) was 39 days and for the noninfected wounds 40 days (23 such wounds). So it is certain that the degree of infection present in the wounds we observed did not delay healing. This does not imply that more extensive infection will not delay the healing of wounds.

Did the presence of sulfathiazole in a concentration of 2.5 per cent retard healing? The results on regeneration of the excoriated wounds and the later study of the rate of growth of hair from the regenerated as compared to a nontraumatized area showed that sulfathiazole in a concentration of 2.5 per cent did not impair regeneration. The results of a comparison of the effect of boric acid ointment and of the sulfagel film show clearly that

sulfathiazole in a concentration of 2.5 per cent, as well as the other ingredients in sulfagel if toxic, is no more 'toxic' than boric acid ointment.

Cannon and Cope clearly demonstrated by treating human excoriated wounds resulting in the area from which a graft was removed that the type of treatment affects the rate of healing. Tannic acid, tannic acid silver nitrate, gentian violet and triple dyes, and Pickrell's solution delayed epithelial healing as compared to boric acid (10 per cent) ointment. However in their experiments a firm dressing was placed over the boric ointment gauze and not over the substances used to produce an eschar. In our experiments, the Pickrell's film and the sulfagel film were bandaged alike, so the firmness of the dressing was controlled. Nevertheless, the wound treated with Pickrell's solution enlarged more and healed more slowly than the wound treated with the sulfagel film.

Although our results have produced no evidence showing that sulfathiazole in a concentration of 2.5 per cent in a petrolatum base or a gelatin base delays healing as compared with boric acid (10 per cent) ointment, this does not mean that higher concentrations of sulfathiazole may not delay healing. Cannon and Cope found that a 5 per cent sulfadiazine ointment did not delay healing of donor graft wounds as compared to boric acid ointment.

TABLE IV—EXPERIMENT E SULFAGEL COMPARED WITH BORIC OINTMENT WITH PRESSURE

Dog N	Size of original wound sq. in.		% maximum enlargement of wound		Days of infection		Days of healing		% diff. wounds operative and healed	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
40	4	4	77	23			29	3	7	5 D
41	4	4	5	77	3	5	30	20	1	7 5 D
42	4	4	55	5	0	30	7	30	1	30 D
43	4	4	47	45			3	3	1	3 5 D
44	4	4	27	205	16	5	24			D
Ave.	4	4	86	37	6	29	4	5	5	1 0 5 D

Left side—sulfagel applied by the "new method"
Right side—vaniline borate gauze pressure

"D" decrease
"I" increase

TABLE V.—COMPARISON OF RESULTS OBTAINED WITH TWO DIFFERENT METHODS OF APPLICATION OF THE SULFAGEL FILM

Size of original wounds in in.		% maximum reduction of wound		Days of infection		Days required for complete regeneration		No. of wounds operative and healed	
Old method	New method	Old method	New method	Old	New	Old	New	Old	New
		96.2	107.5				4.5	D	17
		12.5	9.2			36	36	D	1
		14.5	4.7			40	2.2		17
		30				14			1
		790	37			54		D	5
		5	3			1	26	D	2
		790				64		10	1
		28				42	30	3	1
		47.8				54			D
		17							
4	4	6	6	2	2	42.6	4	3	1

"D" decrease

"T" increase

Does a dressing held firmly on the wound promote healing? It has been demonstrated that compressive dressings decrease the loss of fluid and the incidence of shock in extensive burns (9 12 13). It has been emphasized that pressure dressings are fundamental in the preparation of wounds for and in increasing the extent of take of skin grafts. However we are unaware of an experimental study in animals on the effect of a firmly applied dressing on the rate of healing of a burn.

Our experimentally controlled results show that a firmly applied dressing promotes the healing of burns. For example when the sulfagel film was applied without a firm pressure dressing in 8 dogs (experiment C Table II) the average healing time of the burn was 48.6 days but when applied with a firm pressure dressing in 10 dogs (experiments D and E, Tables III and IV) the average healing time was 32.1 days, a difference of 16.5 days.

Whether the firm pressure acts to compress the capillaries and inhibit the growth of granulation tissue or to bring the dressing into firm contact with the wound so that it serves as a bridge to support the growth of epithelial tissue is conjectural. Both factors may be concerned as pointed out by Twyman who ob-

served that if a piece of adhesive is placed across the middle of a large third degree wound the epithelium will rapidly grow across the wound under that portion of the tape which is in firm contact with the granulation tissue.

A comparison of the results (Table VI) of the use of an ointment (sulfathiazole ointment) and a film (sulfagel) which offers some support with and without a firm dressing indicate that a firm and supporting type of dressing is imperative when a burn is located in a region in which the skin tends to sag or the wound tends to enlarge.

These experimental observations on animals serve to reinforce recent clinical evidence and views regarding the importance of a firm dressing without using unphysiological pressures in the promotion of healing of burns (1 2 12 15) as well as in the prevention of shock (1 8 9 11 12 13).

The rate of healing. In the experiments performed by Carrel and Hartman and Clark on dogs, no initial enlargement of their wounds produced by excision was observed as a rule. The wounds produced by Clark were much smaller than those we produced by excision or by burning; they measured from 1.9 to 3.75 square centimeters and were not dressed. Those produced by Carrel (4 5) were smaller (3.5-5.2 sq. cm.) and dressed with a firmly placed bandage in some instances (4) and in others (5 7) were somewhat larger (34 to 40 sq. cm.) though a cotton pad and shirt were used to cover the talcum powder plain gauze or paraffin dressing. He attributed any enlargement to an error in measurement, which we avoided by training our dogs to stand quietly in a stock during dressing mensuration and photographic procedures. Nevertheless, we observed the same latent period of from 4 to 7 days (4 5 8) before any evidence of healing (decrease in size of wound and fibroplasia) was grossly detectible. Except for the enlargement of the wounds, the curve of healing was similar in contour to those observed by Carrel and Du Nouy (4 5) and Clark.

The wound produced by burning appeared to heal on the average more slowly than the wound produced by excision, unless a firm dressing was used. It is, of course impossible

to determine without a microscopic section just how far the injury extended beyond the actual area of the hot iron. The area actually burned was estimated by inspection to extend beyond the hot iron to involve an area of 25.8 square centimeters instead of the 21.4 square centimeters which was the actual area of the iron. It matters not, however whether 21.4 or 25.8 square centimeters is used as the area burned the average rate of healing was slower in the burn than in the excision wound when a loose dressing was applied. For example, in Table VII compare the figures in columns A, B and C especially B and C in experiments B and C. However when a firm dressing was applied the burn healed as or more rapidly than the excision wound with a loose dressing. For example in Table VII compare the figures in columns B and C in experiments D and E using sulfagel with those in the same columns in experiment B using sulfagel.

The amount and retraction of the scar. The area of the epithelial scar was accurately measured but the amount of fibrous scar could be only roughly estimated by the method we used. It probably would have been preferable to have determined its wet and dry weight and then to have analyzed it for collagen or nitrogen content.

We were interested in obtaining some idea of the size of the epithelial scar and the amount of fibrous scar because the sulfagel contained some potassium iodide. Iodides are supposed to have an histolytic effect, to "aid in the resorption of inflammatory lesions," to mobilize fibrous tissue, and to favor the absorption of fibroses" (10-14). *In vitro* iodides render colloids more soluble and less viscous and hence may decrease the degree of contraction of fibrous tissue though it is conjectural whether in therapeutic concentrations this effect occurs (14).

Referring to Table VI it will be noted that the amount of fibrous scar as roughly approximated by the method we used, is quite constant except in the instance in which (sulfagel ointment treatment of the burn) the wounds healed slowest. In regard to the area of the scar at the time epithelization had been completed it is interesting to note that the average area of sulfagel scars is consistently larger

TABLE VI.—SUMMARY, AVERAGES

Procedure	Max. area, cm. ² increase	Days of infection	Days for healing	Area of scar, sq. cm.	Thick. area of scar	Relative amount of scar	Remarks
Exp't B Sulfagel Excision wound Sulfagel Sulfagel Excision wound	21.4 30 60 200						Loose dressing Loose dressing Loose dressing
Exp't C Sulfagel Burn Sulfagel Burn	61 62 64 66	6 6 6 13	23 23 23 54	24 26 26 33	20 26 26 43	6 7 7 9	Loose dressing Loose dressing Loose dressing
Exp't D Sulfagel Burn Sulfagel Burn	47 43 21 46	6 6 5 5	24 24 43 43	7 7 23 23	26 26 23 23	7 7 7 7	Firm dressing Firm dressing Firm dressing
Exp't E Sulfagel Burn Sulfagel Burn	48 48 6 37	6 6 6 6	20 20 20 20	27 27 27 27	24 24 24 24	6 6 6 6	Firm dressing Firm dressing Firm dressing

Indicates the increase in the size of or the maximum size of the wound after its infection.

(Area of skin actually removed about 20 sq. cm.)

(Area of skin burned by hot iron about 21.4 sq. cm. = the actual area of the burn)

(Area of scar measured on epithelial surface. The thickness measured is that of the fibrous tissue beneath the epithelium)

than the average area of the scars treated with noniodized preparations. This is true regardless of the fact that the wounds not treated with the sulfagel film manifested more initial enlargement. This was also true when the healing time was approximately the same for the sulfagel film and the therapeutic preparation with which it was compared.

This observation suggests that the iodide decreased the extent of contraction of the fibrous tissue. How long this effect might persist is conjectural, because we have not made observations on the extent of contraction of the scar after complete epithelization occurred. If the observation proves to be true it would be of interest to know the effect of orally administered iodides after epithelization.

Since healing occurs by contraction of fibrous tissue as well as by epithelization would the apparent effect of the local application of iodides be beneficial? It was not deleterious in wounds of the size we studied. It might be deleterious in larger wounds which however are usually treated by skin grafting.

TABLE VII.—AVERAGE RATE OF HEALING OR AREA EPITHELIALIZED PER DAY

Type of wound and dressing	Average rate of healing per day expressed as square centimeters		
	According to measurement	According to plan of wound as previously produced	According to size of wound minimally produced
A	B	C	
Experiment B Excision Sulfagel (8 days)	5	67	6
Loose dressing sulfa ointment (8 days)	87	63	63
Experiment C Burn Sulfagel (8 days)	18	23	4.67
Loose dressing sulfa ointment (8 days)		28	20
Experiment D Burn Sulfagel (5 days)	26		6
Firm dressing Pickrell (5 days)	66	39	29
Experiment E Burn Sulfagel (5 days)		63	
Firm dressing Boric ointment (5 days)	67		60
Experiment E and D Burns Average of boric ointment and Sulfagel (10 days)	67	60	67

$$\frac{1}{2} + \frac{1}{2} = 1$$

$$\frac{1}{2} + \frac{1}{2} = 1$$

$$\frac{1}{2} + \frac{1}{2} = 1$$

$$\frac{1}{2} + \frac{1}{2} = 1$$

$$\frac{1}{2} + \frac{1}{2} = 1$$

$$\frac{1}{2} + \frac{1}{2} = 1$$

If in the case of skin grafting iodides should prove to decrease the extent of contraction of fibrous tissue better end results might be obtained.

We should emphasize that the foregoing discussion is only speculative. The larger epithelial scar associated with *sulfagel* therapy may prove to be a "court plaster effect" rather than an iodide effect. We shall not know which until either boric acid ointment with or without potassium iodide or *sulfagel* film with and without potassium iodide have been compared.

SUMMARY

A uniform sized excoriation wound, an excision wound and third degree burn was made on each side of the back of dogs. The effect of several medicated preparations on healing was compared by placing one of the preparations over the wound on one side of the back and another over the wound on the other side of the back. A 2.5 per cent sulfathiazole ointment, Pickrell's solution, which produces a

film, and 10 per cent boric acid ointment were compared with a gelatin film containing 2.5 per cent sulfathiazole, some potassium iodide and enough glycerine and water to render the film pliable.

It was found that a wound produced by removing the skin to the depth of the base of the hair follicles healed in the same period of time when treated with the gelatin film and the 2.5 per cent sulfathiazole ointment. The epithelium healed completely as judged by comparing the hair growth of the regenerated skin with a nontraumatized area.

Using a loosely applied dressing the excision wounds (20.5 sq. cm.) healed in the same time when treated with the medicated gelatin film and the sulfa ointment though the burn wounds (25.8 sq. cm.) healed (complete epithelization) somewhat more rapidly on the average when treated with the medicated gelatin film.

With the use of a firmly applied dressing the burn wounds treated with the medicated gelatin film healed more rapidly on the average than those treated with Pickrell's solution. When the burn wounds were treated with the gelatin film and boric acid (10 per cent) ointment, the healing time was the same.

The medicated gelatin film (*sulfagel*) is best applied by melting some of the film and pouring it over the wound after it gets a sheet of the film is placed over the wound and held in place by a firm dressing.

The incidence of infection was less with the medicated gelatin film than with the other medicated preparations used. But the extent of infection present in the wounds had no effect on the average healing time. Twenty three noninfected wounds healed on the average in 40 days and 29 wounds slightly infected for 3 or more days healed in 39 days.

Evidence was obtained which indicates that a wound produced by burning heals less rapidly than a wound produced by excision. The appetite of the dogs was decreased more by the burn and the burn appeared to increase their susceptibility to respiratory tract infection.

The evidence definitely shows that a firmly applied dressing decreases the time required for the complete epithelization of a burn wound.

The area of the scar at the time the wound had been completely covered with epithelium was larger on the average in all experiments in which the medicated gelatin film was used. The total amount of scar tissue was not significantly greater however. The film contained potassium iodide which is supposed to favor the absorption of fibroses. Further study is required before it can be concluded whether the effect is due to potassium iodide and is advantageous.

Medicated gelatin covered with a medicated pliable sheet of gelatin and a firmly applied gauze or cotton dressing can be used for the treatment of burns and may prove to be more desirable than other preparations now used clinically in the management of burns and extensive skin wounds. Our observations do not indicate that it is superior to a firmly applied boric acid ointment dressing in regard to the time required for the complete epithelization.

(Boric acid ointment was used in these studies because the area of third degree burn was relatively small and a sys-

tematically toxic amount of boric acid was not subject to absorption.)

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DEBRIDEMENT—WHEN AND HOW MUCH?

A Comparative Study of Battle Casualties

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IN the minds of many surgeons there is no longer any argument that débridement should be accomplished at the earliest possible moment and especially in the case of extremities, should be a procedure sufficiently radical to explore the depths of the wound to remove all devitalized tissue, foreign bodies and detached bone fragments, and to permit adequate drainage. The majority of surgeons treating war wounds would adopt this procedure as soon as the patient is seen. Fruchard, on the other hand, draws a distinction between *epulchage* and débridement. The former is essentially the procedure just cited which he feels should be done only in the first 48 hours after injury. He defines débridement as the simple excision of the skin margins of the wound and the establishment of drainage. This, he states, is all that should be done after 48 hours. Ferguson, Brown, Nicholson and Stedman, on the other hand, state that with the local use of sulfathiazole radical débridement appears unnecessary and in many cases actually destructive. In reporting the treatment of 4000 battle casualties aboard a hospital ship they make the following statement, "Bullets often caused no more trauma than might be expected if an ice pick were suddenly thrust through a part and pulled out. Into these simple wounds sulfathiazole was sprayed and a pressure bandage of elastic webbing applied. A patient with a through and-through wound of the leg or thigh was usually able to be up and walking 4 to 5 days after injury and the wounds healed in 7 to 10 days. We have not seen a single case of infection develop in a patient treated in this manner. Perhaps the type of spray used by these writers accounts for the difference in their results. Certainly their experience cited in the last line of the quotation has not been shared by many others. Kessler reporting 1650 battle casualties, encountered 36 cases of gas gangrene (an incidence of 2.18 per cent).

He makes the significant statement that gas bacillus infection did not develop in any wound on which thorough débridement had been done.

The author was on the surgical staff of an evacuation hospital during two campaigns in the Southwest Pacific. A brief résumé of the care given to the casualties in each instance and of the results will suffice to bring out certain important facts.

The first campaign covered a period of 2 to 3 1/2 months during which time practically all the troops involved lived on C rations. Because of supply problems even these were difficult to obtain at times. The tactical situation required many of the troops to make long jungle marches on short rations before making any contact with the enemy. Casualties did not begin to occur in very large numbers until the campaign was about 3 to 4 weeks old. When they did occur the great majority were seen within 4 to 6 hours of injury by small surgical units very near the scene of action. These units had been directed to débride thoroughly and to splint wounds of the extremities. Abdominal wounds were to be subjected to operation as soon as the patient was considered in proper condition for the procedure. Following surgery these patients were moved to the rear as early as their condition would permit. The journey included travel by native litter, jeep plane and a 5 mile ambulance ride to reach our hospital. On the average they arrived about 48 hours after injury.

Upon arrival all were lean thin, almost bordering on emaciation—as one officer put it they are as fine as racehorses—but comparatively few of them showed signs of toxicity. A large percentage had had sulfa drugs orally in amounts sufficient to produce a very mild cyanosis. About 10 per cent of them required a more extensive or a primary débridement because of inadequate drainage from

their wounds, manifested by toxicity. The majority of the patients with chest wounds and some of those with compound fractures even though adequately débrided were among the ones who showed toxic symptoms. In the battle casualties encountered in this campaign there were 10 cases of gangrene, of which 8 were due to bacterial agents the other 2 to blood vessel injury.

There were 14 deaths in this group of cases which were distributed as follows: gangrene 4 abdominal wounds with peritonitis 4 chest wounds with pneumonia or septicemia 3 brain wounds with meningitis 2 and extensive face and neck wound followed by septicemia, 1.

The second campaign lasted only 3 to 4 weeks. The troops involved were moved out of a staging area where diet was adequate and within 4 days the first casualties were back at the hospital. These men were fed on rations during the campaign, a recently developed and more adequate diet than C rations. The medical setup in the forward area was quite similar to that of the first campaign in location and equipment. There were probably not quite so many well trained surgeons in these units as in the first campaign. The method of treatment of wounds of the extremities in this campaign in the forward areas was only the application of sulfanilamide crystals and sterile dressings with adequate immobilization. Any further treatment required in such extremities was to be given in the rear areas. Wounds of brain and serous cavities were to receive immediately the definitive treatment indicated.

Evacuation in this campaign was from the beachhead medical units to barges thence by a 36 to 40 hour water trip to the rear area where a 10 mile ambulance ride completed the journey to our hospital. The patients arrived on the average about 72 hours after injury. These men were well nourished, not thin and emaciated as in the first campaign. However practically all who had wounds of any extent showed evidence of toxicity. Many had their original battle dressing still in place. Temperatures of 102 to 104 degrees F were the rule rather than the exception. Splinting was quite adequate except that too many men had

had Collins hitch or shoe traction applied for several days because of fractures. This procedure has never been sufficiently condemned with in some cases exposure of the tendons is a terrible burden to add to a compound fracture.

Of the 250 patients received during this campaign 54 per cent required débridement upon admission to our hospital. There were 13 cases of gangrene of which 10 were due to bacterial agents or an incidence of 4.0 per cent of bacterial gangrene. To be fair it must be stated that the administering of sulfa drugs in the course of evacuation was not so successfully achieved as was true in the first campaign. Two patients with compound brain injuries and 3 with abdominal wounds were received in this campaign. All had been subjected to operation in the forward area and all recovered readily.

There were 2 deaths in this group (0.8 per cent mortality). It is to be noted that the patients reached us from 2 to 5 days (average 3) after injury consequently there were fewer deaths in the hospital and more in transit. One death was due to gas gangrene of the left arm and a perforating chest wound with hemorrhage. The patient died 30 hours after admission never having responded sufficiently to restorative measures to permit of amputation. The other death was due to suffocation when the patient aspirated a large mucopurulent plug from a very extensive wound of the lower jaw and neck involving the larynx and trachea.

Of the 10 cases of bacterial gangrene 5 were of the exact type Ferguson and associates describe. They had small through and through perforating wounds of extremities (3 legs 2 arms) without bony damage. None had had more treatment than the application of sulfa drugs and a dry dressing.

COMMENT

Personal experience with war wounds leads to a disagreement with the statement of Ferguson and associates that bullet wounds often cause no more damage than an ice pick. It is our belief that high velocity projectiles cause cellular and molecular derangements in the

tissue at a distance from the site of the visible wound. The tendency for war wounds when sutured to break down even after wide débridement gives support to this statement. No surgeon would hesitate to suture an ice pick wound after débridement but very few who have seen much of war surgery would be willing to suture war wounds, especially those of the extremities. Cellular and molecular arrangements are reversible reactions. This is demonstrated by the rapidity with which the adequately débrided *unsutured* war wound heals without further loss of tissue. It is further proved by the success of so called *primo-secondary* suture now advocated by many surgeons. In 4 to 5 days the cells bordering the wound recover from the blast effect of the high velocity projectile and are again amenable to suture.

On the other hand, there are occasional battle wounds which do heal like an uncomplicated ice pick wound even though nothing is done to them. However the assumption of the surgeon who first sees such a wound that this will always be the case is unjustifiable and may lead to catastrophe. As has been pointed out, 50 per cent of our cases with gangrene showed exactly the same injury which Ferguson describes and to which he would do nothing but spray in sulfathiazole and apply a pressure dressing. The magic sulfa wand was never intended to make the surgeon lose sight of good principles. Certainly the simple excision of the wound margins and extension of the incision sufficient for proper inspection of tissues is the due of every patient. One needs see only once the extensive soft tissue damage inside an innocent looking extremity to be convinced of the wisdom of looking at every wound. Naturally after considerable experience with war wounds the surgeon may begin to exercise some selection but the man who has not seen many war wounds should err on the side of radicalism. This implies, of course, a clear knowledge of anatomy the location of essential structures.

Ferguson may well reply that their mortality rate (0.18% in 4039 patients) is hard to excel. However he states that they received a few cases in 12 hours, a somewhat larger number in 2 to 4 days, and the bulk of them 5

to 14 days after injury. It seems quite likely that those who were going to die never reached their hospital ship. More than half of our deaths occurred within 24 to 36 hours of admission and since the average time lapse from injury to admission in our cases was 2 and 3 days, respectively our figures and Ferguson's are hardly comparable. Also since $\frac{1}{2}$ of his patients were navy personnel they may not have been exposed to soil on which natives had lived with their well known lack of sanitation. When injuries are received in this terrain débridement is essential to save all the limbs possible.

In this same connection some surgeons state that débridement of war wounds is more satisfactory if postponed 48 to 72 hours after injury because of sharper differentiation between live and dead tissue after this interval. In the interim it is assumed that bacterial growth will be held in abeyance by large doses of sulfa drugs. This assumption seems contrary to accepted surgical principles. First, because there is as yet no clear proof that sulfa drugs exert any deterrent effect on the growth of clostridia, the organisms most to be feared in war wounds. Second because one can never rely on the adequate administration of sulfa drugs along the line of evacuation of the wounded. Third, because it is so easy to avoid all trouble by adequately opening the wound.

The two series of cases presented do, perhaps, give an unfair comparison. In one series 90 percent of the patients were given adequate débridement and sulfa therapy the other series were given no débridement and inadequate sulfa therapy. The conclusion seems evident that the earlier and more adequately débridement is done the lower will be the morbidity and mortality rates. Certainly several soldiers who have been through our hospital would not now be minus extremities had débridement in their cases been accomplished early. This does not imply criticism where medical service cannot be given in the forward area. But when one can adequately treat brain and abdominal wounds one is not justified in denying treatment to the patient with a wound of an extremity. If the paper of Ferguson and associates has led to this miscon-

ception in the minds of some surgeons it should be corrected at the earliest possible moment.

SUMMARY

A résumé of one hospital's experience with the battle casualties in two campaigns in the Southwest Pacific is given. The pertinent facts are:

1. First campaign was of relatively long duration; food supplies were short; there were 1203 casualties of which 90 per cent were adequately débrided early (4 to 6 hours). Morbidity was low in patients with extensive wounds and the incidence of bacterial gangrene was 0.66 per cent.

2. Second campaign was of short duration;

food supply was adequate; there were 250 casualties. No débridement of extremity wounds was done. Morbidity was high in patients with extensive wounds, and the incidence of bacterial gangrene was 4 per cent.

A plea is made for early débridement which at the very least provides adequate drainage from the wound even if all devitalized tissue is not removed.

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THE PILONIDAL SINUS

Sacrococcygeal Cyst Teratoma¹

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THE pilonidal sinus is an important and serious problem in the armed forces because of its frequent occurrence, the prolonged period of hospitalization sometimes following surgical procedures, and the number of recurrences with or without surgical treatment. Naval morbidity statistics reveal that nearly as many sick days are recorded for this disease as for appendicitis (2). Many surgical procedures have been described in the literature but the actual results observed are yet disappointing. Some unsatisfactory results are due primarily to conditions existing in the armed forces and hospitals. The purpose of this paper is to analyze the results of various procedures as observed in a U. S. Naval Hospital to describe the method that has been the most satisfactory, namely that of modified partial closure, and to enumerate the factors contributing to poor results.

PATHOLOGY

The origin of the pilonidal cyst or sinus is generally accepted as a congenital invagination of cutaneous structures in the midline of the sacrococcygeal area. Microscopically the sections contain islands of epithelium (Fig. 1) or the cyst may be lined with stratified squamous epithelium (Fig. 2). During and after puberty the endocrine stimulus which controls the development of the cutaneous structures (hair, sebaceous glands, etc.) also acts on the isolated pathologic areas of epithelium of the cyst teratoma. Frequently after being traumatized the nodus of epithelium which by this time contains hair follicles and occasionally sweat and sebaceous glands becomes in-

fected (6, 12) because of its location between the gluteal folds and its proximity to the anus. After infection and extension from spontaneous or traumatic rupture or incision and drainage only a small amount of epithelium may be present but extensive infected granulation tissue remains (Fig. 3a and 3b). The microscopic pathology is that of infected granulation tissue (Figs. 4a, 4b and 5) with occasional islands of cutaneous structures (1, 6, 10, 12).

DIAGNOSIS

The diagnosis of pilonidal disease is made from the history of painful swelling in the sacrococcygeal region accompanied by intermittent purulent drainage or by the presence of cutaneous dimples or draining sinuses. Fistula in ano may occasionally be confused with pilonidal sinus; other conditions to be differentiated are furuncle, sebaceous cyst, skin mycoses, lipoma, fibroma, osteomyelitis of coccyx or sacrum, tuberculosis, syphilis, and anthrax (1, 10, 12).

SURGICAL PRINCIPLES AND TREATMENT

The method of modified partial closure here-with described consists of (1) block excision of the pilonidal cyst and sinus, (2) tension sutures which include the presacral fascia, (3) primary closure of the subcutaneous tissue with interrupted sutures, and (4) separation of the skin edges to delay healing of the skin by means of vaseline iodoform gauze placed between the edges.² The delay in skin healing permits escape of wound secretions until firm union of the subcutaneous tissue occurs, thus preventing hematoma formation or serum collections within the wound.

Selection of cases and preoperative care. Excision is not performed in the presence of acute

¹The opinions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large.

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²This method of modified primary closure was devised and used by Dr. Vernon Davis, Presbyterians Hospital, Chicago, Illinois.



Fig. 1. Photomicrograph of cross section through dimple, *D*, of pilonidal area showing lumen of sinus, *L*, with air surrounding infected granulation tissue, *G*. Note microscopic islands of epithelium, *E*, in subcutaneous tissue.



Fig. 2. Photomicrograph of a cross section of a pilonidal sinus, *L*, completely lined with stratified squamous epithelium, *E*, and surrounded by layer of granulation tissue, *G*.

infection. Warm moist magnesium sulfate dressings are applied to the affected area until infection subsides. Often incision and drainage is required to evacuate an infected cyst or abscess, but sufficient time should elapse for infection to subside before radical excision is performed. Probing or injecting dye into the

sinus before or at operation is not advised because of the danger of spreading infection beyond the walls of the sinus or cyst. The operative field is prepared as in any other surgical procedure.

Anesthesia. Spinal anesthesia with 100 milligrams of procaine is used routinely with sat-



Fig. 3 a. Low power and b. high power. Section of pilonidal cyst lined with a small area of epithelium, *E*, but mostly with infected granulation tissue, *G*. The lumen, *L*,



containing many hair follicles, *H*, and debris. Probing or injection of dye could break through soft granulations and spread infection.



Fig. 4 a, left, Low power b, high power Section through pilonidal sinus with hymen, *L*, surrounded with dense infected granulation tissue, *G*. Not absence of

epithelium in sinus tract. Infection or injected dye can easily be disseminated through soft granulation tissue into the surrounding subcutaneous tissue.

isfactory results. Local anesthesia is contraindicated when closure is contemplated because of the danger of spreading infection.

Block dissection. Block excision (Fig 6) is outlined by semieliptical incisions surrounding the sinus openings, and too wide an excision and incision too near the anal orifice are avoided. The dissection is carried vertically

to the sacral fascia with any deviations necessary to include all pathologic tissue. Because of its septic contents the cyst or sinus should not be opened at operation. The coccyx and sacral fascia are left intact. Complete hemostasis is essential and frequently requires transfusion ligatures before closure.

Modified primary closure. Tension sutures of dermal or silk worm gut (Fig 7) are placed about 4 centimeters apart. The subcutaneous tissues are approximated by carefully placed interrupted sutures (Fig 8). The sacral fascia is included in both the deep subcutaneous and tension sutures. The tension sutures are tied snugly over buttons or pieces of rubber tubing and a strip of vaseline iodoform gauze is placed between the skin edges (Fig 9) to permit serosanguineous drainage.

Postoperative dressings. The dressings are applied to seal the wound from the anus. A wide strip of adhesive tape is placed transversely across the lower end of the dressing and the base of the gluteal folds (Fig 9). Tincture of benzoin applied to the skin and allowed to dry partially before the tape is applied makes the seal more secure.

Postoperative care. For the first 24 hours the patient is kept in supine position because of the spinal anesthesia and the firm pressure aids drainage. By the 5th day the dressing is



Fig. 5. Photomicrograph of section through deeply invaginated dermis, *D* of epithelium but sinus tract, *L*, is completely filled with dense fibrous tissue, *G*. Probing or dye injection would be less likely to spread infection through fibrous tissue lining than through soft granulation tissue.

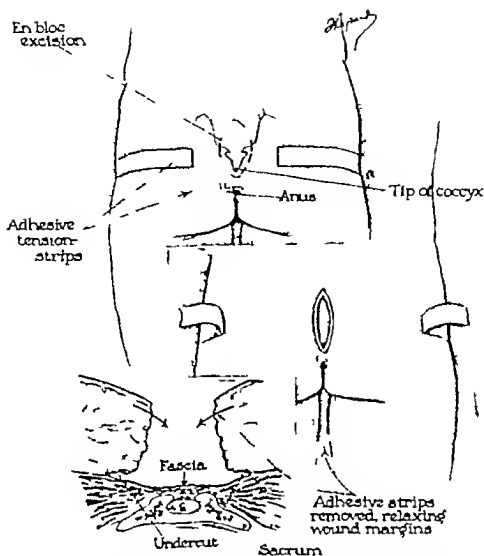


Fig. 6. Position of patient with buttocks retracted widely by means of strips of adhesive tape. Block excision of the pilonidal area is shown with undercutting of the base (insert cross section).

changed but the gauze strip between the skin edges is left *in situ* until extruded by the granulating wound (usually 5 to 7 days). The dressings are not changed again until the 10th day, when the tension sutures are removed. Strict surgical asepsis is used and dressings changed as infrequently as possible unless there is systemic or local evidence of infection. Cathartics are not advised because of the danger of soiling the dressings, but mineral oil is advantageous in aiding defecation. Bed rest is continued until the tension sutures are removed. Defecation should be performed in upright position and the anus cleansed forward to avoid soiling of the dressing. The hair at the wound edges is kept

closely shaved until the scar is firm. Trauma to the operative site should be avoided for some time after healing is complete.

REVIEW OF CASES

The summary of 150 cases treated in the U S Naval Hospital St Albans Long Island New York is shown in the adjoining tables.

The results obtained with open pack technique in 29 cases is shown in Table I. Group 1. In this group postoperative care generally consisted of early daily dressings, sitz baths and local application of various antiseptics. Delayed healing (126 and 120 days) occurred in a quiescent asymptomatic case and in 1 case of recurrence. Slow healing was the fore

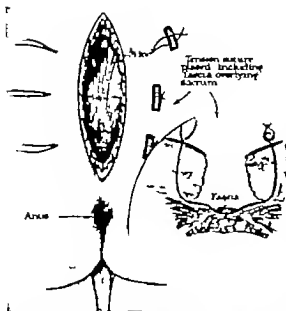


Fig. 7. Tension sutures through skin, subcutaneous tissue, and sacral fascia to approximate the wound edges and obliterate dead space.

most disadvantage of this method as evidenced by the average healing time of 63.1 days. Observations in this group revealed that the end result is sometimes a wide tender scar which is very susceptible to trauma such as the following case:

CASE 5. A 32 year old male was admitted complaining of drainage from a tender area at the base of his spine for 1 week. Examination revealed an acutely inflamed pilonidal sinus which was discharging pus. The sinus was treated with warm moist compresses for 9 days. A block excision of the pilonidal sinus was done and the wound packed open. The wound granulated slowly with daily sitz baths and dressings. Sixty-six days after operation he returned to duty with wound healed. One day later he was readmitted with the scar reopened. Examination revealed that the wide tender operative scar which measured by 5 centimeters had broken open for a distance of 3 centimeters. Sitz baths were given and the wound was treated daily with antiseptics and dressed. Two ty-four days later (total convalescent time 90 days) the wound was finally healed.

In Table I Group 1 shows the results of partial closure methods in 39 cases. Tension sutures alone were used for partial wound closure which were usually removed on the 4th to 8th postoperative day. In most cases

sitz baths and daily changes of dressings were started on about the 4th day and continued until the wound healed. Acute wound infection occurred frequently (41%) and there were 2 cases of delayed healing (51%) and 3 cases of recurrence (7.9%). The average healing time¹ in the cases of this group was 49.5 days.

In Table I Group 3 shows the results of various methods of primary closure. The postoperative care was not uniform in this group. Cotton suture material was used in the majority of these cases. Three cases of serious wound infection were reoperated upon later because of delayed healing. Postoperative infections occurred frequently (46.7%); most cases could be attributed either to operating before infection had subsided or to contamination from the anus. Hematoma formation and serum collections beneath the skin were not infrequent (13.3%). Rupture of the scar occurred in 4 cases (8.9%) which in 2 instances was due to accumulation of serum beneath the scar. The average healing time of this group was 43.4 days.

In Table I Group 4 shows the results of the method of modified partial wound closure herewith presented (37 cases). Complete heal-

¹The term "healed" as used in this article means complete approximation of the scar and absence of fibrous crusts. By "healing time" is meant the time required for complete healing after operation.

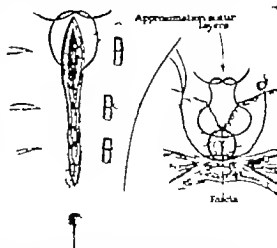


Fig. 8. Closure of subcutaneous tissue by means of 2 layers of interrupted sutures. The deep layer of sutures includes the fascia overlying the sacrum.

ing was observed frequently within 14 days and 50 per cent healed within 3 weeks. Three cases had subacute infection at operation and all 3 developed wound infection with retarded healing. Four postoperative infections resulted from wound contamination. Two wounds reopened as a result of direct trauma. The end results of this group were very satisfactory requiring less than 50 per cent of the mean healing time compared to other procedures. There were 2 recurrences (5.4%) and the average healing time was 26.6 days. No hematoma or serum collections occurred within the wound.

Table II shows the effect of the use of sulfonamides in cases with wound closure. The local use of sulfanilamide powder (2 to 5 gm) was observed to be of little value in preventing postoperative infection but sulfadiazine given orally (1 gm every 4 hrs) appeared to be effective.

Of 25 cases with gross evidence of acute pilonidal infection at the time of operation 23 developed postoperative wound infection and 5 had recurrences. Most of the 150 cases herewith reviewed were followed for about 3 months.

TABLE I—PILONIDAL SURGERY—RESULTS OF VARIOUS PROCEDURES

	Group 1 Open pack method		Group 2 Partial closure		Group 3 Primary closure		Group 4 Modified partial closure	
	N	Per cent	N	Per cent	N	Per cent	N	Per cent
Cases	29		30		45		37	
Healing time—days								
Maximum	20		20		0		74	
Minimum	20		5		4			
Mean	29		0		4.2			
Average	5		20.5		13.4		20.6	
Complications								
Infections	22	76		4	9	20	7	19
Hematoma		0		6	6	2.2		7
Delayed healing	3	3		5	3	6.7		—
Rupture of scar	3	3		5	4	8.9		5
Recurrences					7	15.6		5

*Practically all cases in which the open pack technique was used had wound infections, hematoma, or delayed healing, but no acute wound infections appeared in this group.

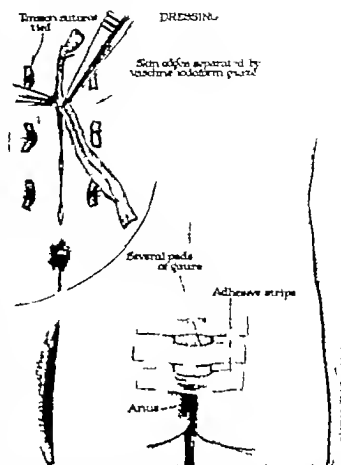


Fig. 9. Strip of vaseline iodiform gauze separates the skin edges to delay skin healing and to permit drainage. The iodiform gauze stimulates formation of granulation tissue and is spontaneously extruded from the wound by the 5th to 7th postoperative day.

FACTORS CONTRIBUTING TO UNSATISFACTORY RESULTS

Postoperative infection delayed healing and recurrence of the disease account for most of the poor results following operation. In most cases the occurrence of these complications can be explained upon clinical or pathological bases.

Acute infection is an absolute contraindication for radical surgery and should have completely subsided before excision is undertaken. Despite this precaution postoperative infection is observed but its frequency results from one or more of the following factors: (1) probing or injecting dye into the infected sinus which is lined with soft granulation tissue; (2) opening sinus accidentally or intentionally at operation causing wound contamination; (3) inadequate removal of the islands of

TABLE II.—PILONIDAL SURGERY—EFFECT OF SULFONAMIDES ON INCIDENCE OF INFECTIONS

	No. cases	No. infections
No sulfonamides used	66	12
Local sulfonamides	40	16
Oral sulfonamides	4	

*Only those cases in which wound closure was performed were included

epithelium or sinus tracts (4) incomplete postoperative dressings which do not protect the wound from contamination and (5) failure to consider surgical asepsis because of administration of cathartics and sitz baths during the early period of wound healing.

Delay in healing is usually due to extensive wounds from too radical excision, nonclosure of the wound, careless or incomplete approximation of tissues in wound closure, presence of foreign body (infected suture material and unshaven hair at wound edges) and infected granulations.

Recurrences are observed in all types of surgical procedures and are due occasionally to inadequate excision of the sinus but usually to infected granulation tissue-lined pockets in the depths of the wound (18). Other causative factors are postoperative infection, poor scar formation and hematomas or serum collections beneath the scar.

OBSERVATIONS

The military surgeon can reduce the morbidity of pilonidal disease by (1) operating only upon those patients in whom surgery is necessary, (2) allowing infection to subside completely before operating, (3) employing a satisfactory method of closure after complete excision of the pathology and (4) focusing more attention on postoperative care.

Many quiescent asymptomatic pilonidal cysts are discovered in routine physical examination of military personnel and are referred to the surgeon for excision. Since all sacrococcygeal cysts or sinuses do not cause subjective symptoms, it is unwise especially in the armed forces to operate on these patients who may never require surgery and therefore surgery may result in unnecessary morbidity during wartime.

Complete excision is one of the essentials of pilonidal surgery. Permitting the wound to heal entirely by secondary intention results in prolonged healing time and in a wide delicate scar (24). On the other hand, primary skin closures prevent subcutaneous drainage causing subcutaneous hematomas or serum collections which become infected and result in sinus formation (1, 18). The advantages of primary wound closure are more rapid healing and smaller scars. David Gage Hookstra, and others recommend closure and present substantiating evidence. Open pack methods require from 45 to 118 days for healing (11, 15) and the scar is very susceptible to trauma (24) while closure methods require from 10 to 43 days (2) and the narrow scars are more resistant to trauma. The incidence of recurrence of the cyst or sinus following open pack operation is shown rather conclusively by Kleckner to be less than that of the closure methods but this is not supported by others (12, 26). Recurrences can be decreased by adhering to Halsted's surgical principles, i.e. atraumatic surgery, strict aseptic technique, complete hemostasis, and accurate approximation of tissues in wound closure. The time saved in performing satisfactory wound closure more than compensates for the time required in treating the occasional recurrence.

Meticulous care of the wound and maintaining asepsis during healing are rewarded by more rapid healing and fewer recurrences. A small detail frequently overlooked is keeping the wound edges shaved to prevent growth of hair into the wound.

Local application of sulfonamides are of little value for prophylaxis of infection (17) but oral sulfonamides seem to be of definite value. Heliotherapy (25) and roentgen therapy (7, 21) are advised for treating wound infection and delayed healing.

SUMMARY AND CONCLUSIONS

The pathology and treatment of the pilonidal sinus are discussed. The factors which contribute to postoperative infection, delayed healing, and recurrences are enumerated and briefly discussed.

A method of excision and modified partial closure is presented which diminishes the in-

cidence of recurrence heals almost as rapidly as primary closure and results in a narrow firm scar

Morbidity of pilonidal disease can be reduced by (1) operating only on those cases in which surgery is necessary (2) allowing infection to subside before operating (3) employing a satisfactory method of closure after complete excision and (4) focusing more attention on the postoperative care

Surgery is not necessary in the absolutely quiescent asymptomatic case especially among members of the armed forces during war time

In general satisfactory results of pilonidal surgery are directly proportional to the meticulous care used in preoperative preparation in the surgical technique and in postoperative care. Oral sulfadiazine is of value in prophylaxis of wound infection

The results of treating 150 cases by various surgical methods are analyzed

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THE PHYSICIAN BLOOD TRANSFUSION THE Rh FACTOR AND ERYTHROBLASTOSIS FETALIS

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As a result of the war many thousands of physicians have migrated into our armed forces, leaving in most localities only skeleton staffs to carry on the work of universities, colleges, hospitals and civilian practice. The burden of responsibility for safeguarding the health of the nation falls upon the older physician who *ante bellum* had largely limited his practice to a specialty. In our smaller cities, particularly, he has been pressed into service as, among other things, accoucheur or pediatrician or both—roles which he had gladly surrendered to his younger colleague before the latter went into service. Because of earlier experience in these cases the surgeon and the gynecologist as well as the obstetrician are probably most affected by increased demands for their professional attendance upon both the parturient and the newborn.

Thus today and probably for the duration of the war such physicians must supervise more blood transfusions, perform more obstetrical deliveries, and prescribe more neonatal conditions than ever before.

It is precisely in these cases that knowledge of the Rh factor described currently in the literature and discussed editorially in scientific publications (3) may enable the attendant not only to avoid serious intragroup transfusion reactions, but potentially to save the lives of some mothers and babies. These reasons, and the belief that it is an obligation for every medical or surgical attendant to acquaint himself with the rôle of the Rh factor in isommunization form the chief incentive for this presentation.

DEFINITION OF TERMS

To avoid confusion in the subject under discussion it is best that the physician refresh

his memory of certain facts concerning some of the properties of the blood cells and blood serum of humans. An explanation of certain terms used in this presentation and commonly employed in immunology will be found in Table I.

THE BLOOD GROUPS

It will be recalled that Landsteiner in 1901 (7) was the first to describe isoagglutination in man and recognized a congenital difference between the agglutinogens (red cells) (antigens) and agglutinins (serum) (antibodies) found in different individuals of the human species. On the basis of isoagglutination (causing agglutination) of the red corpuscles of man he and his pupils (9) first described the four blood groups O, A, B and AB by which we may classify the blood of each individual of the human species. These groupings are hereditary according to Mendelian principles.

For purposes of description we may consider each agglutinin (serum) and its corresponding agglutino-gen factor (cells) as isomers or homologous images of each other and graphically represent them as such (Fig. 1). Thus agglutinin A is the specific antibody of its homologue or image, the A agglutino-gen or antigen. Likewise B agglutinin is the specific antibody of B agglutino-gen. When both A and B exist together in the same specimen we may similarly represent them graphically (Fig. 1) as AB.

A specimen of blood from an individual in group O (Fig. 2) will then be seen to be divisible into its cells, which contain no agglutino-gen and its serum in which both A and B agglutinins are present. In the same manner (Fig. 3) the blood of group A can be separated into its cells, containing A agglutino-gen and its serum containing B agglutinin. Group B blood (Fig. 4) is the reverse of group A containing B agglutino-gen in its cells and A

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TABLE I.—TERMS, SYNONYMS, AND DEFINITIONS

Terms	Synonym	Definition
Agglutinogen	Antigen	The agglutinable substance for which there is specific antibody in the blood serum or which under proper conditions may stimulate the formation of such an antibody
Agglutinal (serum)	Antibody	The specific substance which causes clumping of its corresponding (homologous) agglutinogen (antigen)
Agglutination	Clumping	The result of specific agglutinin acting upon its corresponding agglutinogen
Isoagglutinin	Isoantibody	An agglutinal capable of agglutinating the agglutinogen (red cells) of another individual of the same species
Isoimmunization		The production of specific agglutinal or antibody in the serum of another individual of the same species by injecting the red cells of one species into the blood of another animal
Heteroimmunization		The production of specific antibody (agglutinal) in the serum of an individual of another species

agglutinin in its serum Group AB (Fig 5) is the reverse of group O containing both A and B agglutinogen in its cells while the serum contains no agglutinins.

It is to be recalled here that the cause of most blood transfusion reactions is dependent upon *agglutination of the donors cells by the serum of the recipient* due to the presence of specific isoagglutinin (antibody) in the latter. It is always desirable therefore to use as a donor an individual who is in the same blood group as that of the recipient. This however is not always practicable. Actually the serum (isoagglutinin or antibody) of the donor becomes so diluted by the circulation of the recipient that the agglutinating property of the donor's serum (upon the recipient's cells) is rendered relatively impotent. Accordingly the diagram shown in Figure 6 depicts the clumping effect upon cells (donor) by the agglutinins of the various sera (recipient). From this chart it becomes apparent why

group O is referred to as universal donor (cells without agglutinogen) and group AB as universal recipient (serum without agglutinin)

OTHER BLOOD FACTORS OR TYPES AND THE Rh FACTOR

There exist in the human red blood corpuscles of all four blood groups certain other factors or agglutinogens (antigens) for which no corresponding isoagglutinins have been found in human sera. Such types may be diagrammatically represented (Fig 7) as M N MN (M and N) and P. These antigens (without corresponding antibodies) do not

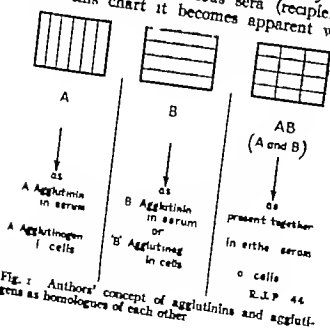


Fig. 1 Authors' concept of agglutinins and agglutinogens as homologues of each other

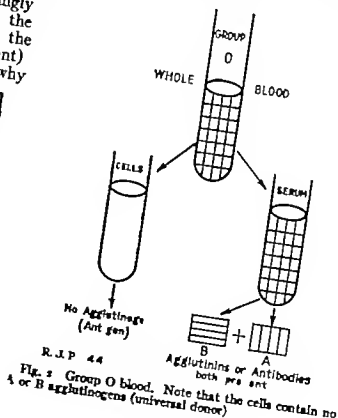


Fig. 2 Group O blood. Note that the cells contain no A or B agglutinogens (universal donor)

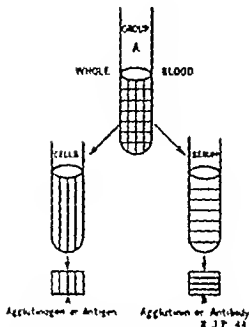


Fig. 3. Group A blood contains A agglutinogen in its cells and B agglutinin in its serum (the reverse of group B).

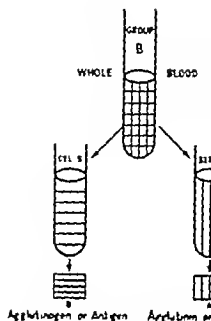


Fig. 4. Group B blood contains B agglutinogen in its cells and A agglutinin in its serum (the reverse of group A).

produce human transfusion reactions. However it has been shown that they do produce corresponding agglutinins if the human red cells of that particular type are injected into animals, such as the rabbit (heteroimmunization).

In 1940 Landsteiner and Wiener (8) injected blood from the *Macacus rhesus* monkey into rabbits thus developing agglutinins in the rabbits' serum which clumped the red cells of the monkey. They also observed that this same rabbit serum (agglutinin) clumps not only the red cells of the monkey but also the red cells of 85 per cent of humans, regardless of their blood group. The red cells of the remaining 15 per cent of humans are not affected (show no evidence of clumping) by the antimonkey agglutinins. Obviously this (15 per cent) group of humans have in their red cells none of the agglutinogen (antigen) which is present in the *Macacus rhesus* cells and in the cells of 85 per cent of humans. This particular agglutinogen (antigen—Fig. 7) is referred to as the *Rh factor*. Individuals whose cells contain this antigen (85 per cent of the random population) are termed Rh positive (Rh+). The Rh factor is also trans-

mitted to offspring as a Mendelian character. Those individuals whose erythrocytes do not contain the antigen (15 per cent of the random population) are termed negative (Rh—).

THE Rh FACTOR AND ISOIMMUNITIES

Experience in both military and civilian practice has shown that transfusion of Rh— blood (agglutinogen) into Rh+ individuals, even of the same blood group, causes the development of antibodies (specific Rh+ agglutinins) in the recipient's serum (isoimmunization). In a subsequent transfusion of Rh— blood into the same individual (or into another individual) these antibodies (agglutinins or antiserum) produced in the serum of the recipient by the Rh+ cells of the earlier transfusion cause agglutination and destruction of the Rh+ cells of the donor. Such an isoimmunization reaction may be severe and even cause death.

It is now an established fact that individuals develop specific anti-Rh immunity (agglutinins or antibodies) when transfused with Rh+ blood even though both donor and recipient are of the same blood group. In subsequent

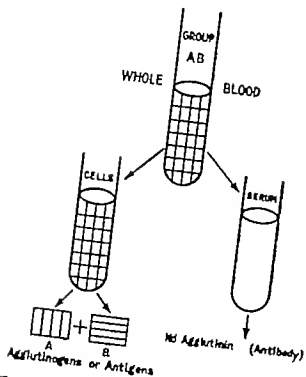


Fig. 5 Group AB blood. Note that the serum contains no A or B agglutinins (universal recipient) R.J.P. 44

fusions of Rh+ blood these agglutinins produce the reaction. The prevention of this accident lies in the employment in these cases, of blood from an Rh- donor of the proper blood group who has not previously been immunized

THE Rh FACTOR AND ERYTHROBLASTOSIS FETALIS

Clinically most cases of erythroblastosis fetalis (acute hemolytic anemia) are recognized in the newborn as either universal edema (jaundice) or as a marked anemia (congenital). The condition is usually apparent at birth. Predominantly in nearly every instance there is clinical evidence of blood destruction and liver involvement, accompanied by microscopic evidence of blood regeneration. The mortality rate varies from 50 to 100 per cent. Recently Levine (12) and his associates have shown that about 90 per cent of these infants have in their blood cells the Rh factor inherited from the Rh+ father. The mother lacks this factor in her blood cells (Rh-). The blood destruction observed in the newborn is held to be dependent upon the presence

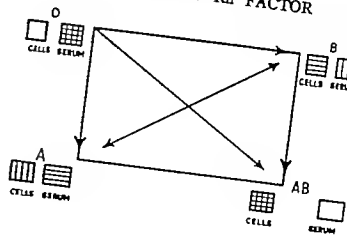


Fig. 6. Note that O cells (universal donor) are not agglutinated by the other groups while AB serum (universal recipient) does not agglutinate the cells of any other group. R.J.P. 44

in the baby's serum of a specific Rh antibody (the anti Rh agglutinin or antibody) which has been transferred from the mother to the baby *in utero*. Our findings in a series of 25 cases tend to confirm this view as do the observations (4 5 6 10) of many others

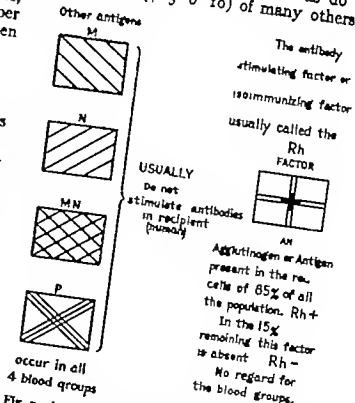


Fig. 7 Authors concept of other agglutinogens or factors sometimes present in human red cells. Of these the Rh factor is of great significance. R.J.P. 44

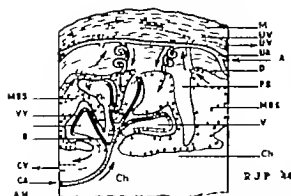


Fig. 8. Diagrammatic section through human placenta. *M* uterine muscle *UV* branch of uterine vein, *UA* branch of uterine artery *D* decidua *PS* decidua parietalis *MBS* maternal blood sinus *V* villus *Ch* chorion frondosum *AM* amnion *CA* branch of umbilical artery *CV* branch of umbilical vein *PS* villus branch of umbilical artery *VV* vein withdrawing blood from villus

MECHANISM OF PRODUCTION OF ANTI RH AGGLUTININ

It is our concept, and that of other observers (14, 17) that the mechanism of production of the Rh+ antibody is based upon events which transpire within the placenta itself.

The medium (Fig. 8) for the interchange of gases, water and nourishment between mother and baby is the fragile wall of the placental villus, *V* a trophoblastic projection of the chorion frondosum itself *CA*. Through an arteriole, *FB* each villus is supplied with fetal blood by a branch from one of the umbilical arteries, *CA* while a corresponding venule, *VV* eventually returns the blood to the fetal circulation, *C*. The delicate placental villi are bathed in pools of maternal blood *MBS*, in the intervillous spaces. The maternal blood is carried to these spaces by minute branches of the uterine artery, *UA* which are usually found in relation to the decidua septa *PS* while corresponding veins return it eventually to branches, *UV* of the uterine vein. Constant circulation is assisted by the uterine contractions which occur at intervals throughout every pregnancy. Normally the blood of the child circulates inside the villus, while the maternal blood circulates outside this delicate structure. The relationship is so close that osmosis readily takes place through the villus wall. It has been estimated that if all the villi of a placenta at full term were placed end to-

end their combined length would exceed 11 miles (11).

That the placenta is extremely susceptible to the effects of tumors, trauma, and disease has long been known. This is not a surprising observation in view of the complex structure and function of this organ and of the fact that the more complex an organ the more delicate and vulnerable to injury it becomes. (13) Careful scrutiny of the placenta (1) will reveal in nearly every instance the unmistakable evidences of one or many areas of old or recent pathologic alteration. Such scars, varying in size from pin-head to several centimeters, have been designated by a confusion of terms, such as infarction, hepaticization, placentalitis, necrosis, apoplexy, etc. Actually each such scar represents merely the evidence of a previous placental injury.

Since the most delicate portion of the placenta (chorion frondosum) is the villus itself this structure is the most susceptible to injury (rupture) either as a result of apoplexy or of hemorrhagic infarction or of direct trauma. Whatever the etiologic factor any violent break in the continuity of the vessels of one or more villi will result in hemorrhage of fetal blood cells (Fig. 9 *N*) into the maternal circulation *MBS*. From here the fetal blood elements, *VUV* are carried into the uterine vein *U* and thence into the general circulation of the mother. Such a hemorrhage may be minute and apparently insignificant or of considerable size. Either may produce most serious sequelae.

If the baby's cells contain the Rh antigen (Rh+) while those of the mother are without the antigen (Rh-) a variable degree of iso-immunization is inevitable. The Rh+ cells of the baby stimulate the Rh- mother's blood to produce the specific anti Rh antibody (anti-Rh+ agglutinin). This antibody not only becomes present in the blood serum of the mother but is readily transmissible, as are many toxins and antitoxins, through the placental filter (the walls of the villi) into the circulation of the infant *in utero*. It is the action of this antibody upon the Rh+ cells of the baby which produces the disease entity which in about 90 per cent of the cases we recognize as erythroblastosis fetalis. In most

of the remaining 10 per cent the disease apparently depends upon similar genetically related antigens (such as those designated as HR or the A and B antigens) present in the baby's cells but absent in those of the mother.

DIAGNOSTIC FEATURES

The earlier the diagnosis is made and appropriate treatment instituted the better becomes the prognosis. If in any expectant mother the history reveals a reaction to any former blood transfusion or an unexplained spontaneous abortion, miscarriage, or still born infant (especially if her first baby was normal) one's suspicion should be aroused as to the possibility of isoimmunization. The history of the birth of an anemic, jaundiced or edematous infant, or a combination of any of these is presumptive evidence of this condition. During labor a bile stained or amber colored amniotic fluid, with or without signs of fetal distress should place the accoucheur on guard, and indicate to him the necessity for immediate Rh factor determinations upon the mother and upon the baby (cord blood) as soon as delivery occurs.

In any newborn baby exhibiting anemia, increasing jaundice edema (hydrops) enlarged liver and spleen, with a blood smear showing evidence of erythroblastemia not always manifest, one must rule out isoimmunization. Some additional features which we have noted in a number of our cases, usually within the first 24 to 48 hours are lethargy sometimes alternating with convulsions dark amber urine, diffuse or localized petechiae unexplained fever and an abnormally low platelet count.

MANAGEMENT

Usually the first Rh+ child of an Rh- mother and an Rh+ father will survive (in sufficient or undeveloped antibody?) Subsequent pregnancies may result in abortion or miscarriage or the child near term may succumb to the disease *in utero* and be stillborn or survive the ordeal of labor only to expire within a few hours or days from the effects of the disease. An Rh- baby of course is unaffected. The oxygen tent and immediate transfusion of 60 cubic centimeters of whole blood from an Rh- donor repeated at 48 hour in



Fig 6. Diagrammatic illustration of rupture of placental villi. V fetal blood from villus vessels pouring into maternal blood sinus, MBS. Fetal blood enters maternal uterine vein at UV. (See text)

tervals during the first 2 weeks of life offer the best prognosis. The use of the mother's blood is contraindicated (Rh antibodies) as is that of the father (Rh+ cells). Milk from the mother probably should not be given the baby—Rh antibodies—(18). Usually about 2 weeks are required before the anti Rh substance becomes eliminated from the baby's circulation.

As in any other obstetrical case an Rh- mother may herself require transfusion. In this event it must be emphasized that she requires Rh- blood.

BLOOD GROUPING TESTS

Blood grouping or typing is essential before every transfusion. A drop of known group A serum is mixed on a glass slide (ordinary room temperature) with a drop of 1 to 2 per cent saline suspension of the cells to be tested. To another drop of such cells a similar amount of group B serum is added. Microscopic examination is made 20 to 30 minutes later. If no agglutination occurs with either sera, the cells belong to group O. Agglutination by A serum signifies that the cells are those of group B. Agglutination by B serum means the individual belongs to group A. If both sera cause agglutination the cells are those of group AB (Fig 6).

Ideally all prospective donors and recipients should also be typed for Rh factor. This determination is especially important in patients who have received one or more previous

transfusions and in women who give a history of toxemia, miscarriage, stillborn, or erythroblastotic children. All available relatives of known Rh— persons should be typed since it is known that in these individuals a greater percentage of Rh— persons will be found than among the relatives of those who are Rh+.

By using known anti-Rh serum¹ the typing technique is simple. It is important here to bear in mind, however, that the anti-Rh antibody is a "warm agglutinin. That is, the agglutinin or antibody is most effective at body temperature—37 degrees C. Variations of this temperature definitely interfere with the test. In our laboratory (15) our directions follow a modification of that employed by The Certified Blood Donor Service as follows. In a sterile 3 by 3/8 inch test tube place 4 cubic centimeters of saline to which is added one drop of blood. Centrifuge for 1 minute. Decant the supernatant fluid to remove fibrin and then add 4 cubic centimeters of additional fresh saline to suspend the washed cells. Place 2 drops of this suspension in another 3 by 3/8 inch test tube, add 2 drops of known anti Rh serum and shake lightly. Place this tube in a water bath at 37 degrees C. Shake gently every 15 minutes and after 1 hour remove from water bath and centrifuge for 1 minute at not over 500 revolutions per minute. Then agitate gently observing the precipitated cells. Examine for clumping both macroscopically and microscopically. If there is no clumping the cells are considered Rh negative. Rh+ cells will be clumped.

Rh testing sera should be of high anti Rh titer. Blood from a recently delivered Rh— mother who has given birth to a baby with erythroblastosis usually possesses agglutinin of high titer. This titer however rapidly deteriorates and often, after a few months, may have entirely disappeared.

The Blood Grouping Laboratory at Boston, Massachusetts, under the direction of Dr. Louis K. Diamond (2) is engaged in the study and concentration of anti Rh sera, and solicits specimens of blood for study. Specimens thus submitted to this laboratory will be concentrated without charge, and a portion

returned to the sender. The remainder is used for Rh testing by our armed forces.

SUMMARY

1 Every physician who performs blood transfusions, or who has under his care expectant mothers or newborn babies, should be thoroughly familiar with the fundamentals concerning the blood groups and isoimmunization.

2 The blood groups are graphically illustrated and explained.

3 Other blood factors, especially the Rh factor are graphically illustrated and the special importance of the latter in both civilian and military practice is emphasized.

4 The relation between the Rh factor transfusion reactions, maternal isoimmunization, and erythroblastosis fetalis is presented, with illustrations of the placental mechanism involved during certain pregnancies.

5 The diagnosis and proper management of erythroblastosis and of the Rh+ isoimmunized patient are outlined.

6 A simple technique for accurate Rh testing is included with that for the ordinary tests for blood grouping.

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¹Available serum (anti-Rh serum) for testing for Rh factor may be obtained from The Certified Blood Donor Service of Jamaica, New York.

THE USE OF LYCOPODIUM AS AN AGENT TO CREATE A COLLATERAL CIRCULATION TO THE MYOCARDIUM FROM THE PERICARDIUM

Preliminary Report

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THE medical treatment of coronary artery disease has certain definite limitations. There is a discrepancy between the blood supply to the myocardium and the blood demand by the myocardium. The medical answer to this law of supply and demand is essentially to decrease the demand for more blood by limiting the activities of the whole body (thus decreasing the basal metabolic requirement) to increase the blood supply by certain vasodilating drugs and to bring in the element of time to allow nature to develop a collateral circulation.

Nature plus the element of time develops a collateral circulation in one or more of three ways. The first way is to elaborate intercoronary anastomosis. Although the coronary vessels are essentially end arteries there are minute intercoronary communications (1, 3). If coronary artery disease progresses slowly these communications are gradually dilated. (2) The second way that nature works is to create an adhesive pericarditis, thus bringing blood vessels in from the pericardium. This process is illustrated by finding at autopsy an old infarct with the pericardium adherent to the heart at this area in a patient who has succumbed to noncardiac causes.

The third way that nature operates is via the thebesian system. The thebesian orifices are located in the walls of the auricles and ventricles. These communicate with the coronary vessels via capillaries. It has been shown experimentally (2) that the heart can be effectively nourished by blood passing from the chambers of the heart through the thebesian vessels then back to the coronary veins. This mechanism can operate only in the presence of a gradual coronary occlusion.

An example of this triple action by nature following a sublethal coronary occlusion is as follows:

The infarction creates an inflammation of the heart. This inflammation can stimulate intercoronary communications, can create an adhesive pericarditis at that area and can stimulate the thebesian system. In the case of slow narrowing of the coronary vessels, only mechanisms 1 and 3 are brought into play.

The surgical attack on coronary artery disease (exclusive of sympathectomy and thorodectomy) is essentially the stimulation of the aforementioned 3 mechanisms. In place of or with the adhesive pericarditis (which is pericardiopleurocardiopexy) there have been added at times cardiomyopexy, cardiopneumopexy, cardio-omentopexy and similar procedures.

About 2 years ago we became interested in the possibilities of surgical attack on this disease. We repeated some of the experimental work and tried some new agents. One of these lycopodium powder instilled within the pericardial sac, impressed us so much with its ability to create a very vascular adhesive pericarditis that we concentrated on this powder. Because of limited housing facilities the preliminary work was done on rabbits. Then dogs were used. Since the results were the same on rabbits as on dogs we went back to rabbits as they were easier to handle and take care of. A total of 4 dogs and 9 rabbits is concerned in this report.

The operation consisted of opening the pericardial sac, placing the lycopodium powder on the anterior lateral and inferior surfaces of the heart and then closing the pericardium with a purse-string suture. The amount of



Fig. Photomicrograph of section from rabbit heart. The lycopodium particles (oval-shaped, often containing granules) are seen ingested by multinuclear giant cells. Some giant cells contain more than one lycopodium particle. The cellular infiltration about the giant cells is chiefly mononuclear. Eosinophils are present. On the very bottom is small piece of heart muscle. But even this heart muscle and the lycopodium layer is the remains of the epicardium. Very little fibrous tissue is present.

lycopodium powder used was that amount held in 4 to 5 medium sized bone curettes.

Silk technique was used throughout. Positive lung pressure was maintained in the dogs by an intratracheal catheter. On the dogs, the heart was reached through a rib resection. On the rabbits the approach was by splitting the sternum and then gently retracting the unopened pleurae to expose the pericardium. Positive lung pressure was used, however by means of a rubber glove slipped over the animals head with one finger connected to a tank of oxygen. All animals were anesthetized with nembutal given either intravenously or intraperitoneally. At the end of 6 to 8 weeks, the animals were killed and sections were taken from the heart for examination and study.

In all cases in which lycopodium was used the pericardium promptly became adherent to the epicardium. One rabbit that died 72 hours after operation of acute dilatation of the stomach showed the pericardium already adherent to the left ventricle. Microscopic report on this heart showed "an amorphous exudate over the epicardium, fixing and surrounding the lycopodium particles. Several enlarged epicardial capillaries are seen, one of them forming a loop reaching close to the site of the exudate."



Fig. 2. Photomicrograph of section of rabbit's heart. It shows long curved newly formed blood-filled vessel surrounded by lycopodium granules. The adherent epicardium (below the fat) is not shown. The thickened pericardium is seen across the top of the section.

The normal unoperated upon pericardium has a thin glistening appearance. It is transparent. After lycopodium has been deposited within the pericardial sac the pericardium becomes thickened loses much of its glistening surface and the underlying heart is seen only with difficulty. The thickening of the pericardium however is not due primarily to fibrosis as very little fibrous tissue can be seen in the microscopic sections. Grossly there is no fibrosis seen. The adhesions created by this powder are limited chiefly to the areas where the powder was placed. At the periphery of the adherent areas the pericardium merges gradually again to become thin glistening and translucent. The adhesions created between pericardium and epicardium are of the soft variety. There is very slight motion of the pericardium when the finger is gently passed over it.

Microscopically the type of reaction caused by lycopodium is similar to that seen in the body when a foreign substance is present. Large multinuclear giant cells ingest one or more lycopodium particles (Figs 1 2 3). Surrounding the giant cells there is a cellular infiltration that is predominantly mononuclear but often shows a moderate number of eosinophils. The mononuclear cells are the



Fig. 3. Photomicrograph of a section of rabbit's heart. It shows a large curved blood filled vessel. On the left are seen lycopodium granules.



Fig. 4. Photomicrograph of a section of rabbit's heart. On the left is seen the lycopodium layer on the right is the heart muscle. The arrows point to the ends of a blood-filled vessel, one end of which is in the heart muscle, and the other end is straddled by two particles of lycopodium. The arrow on the upper left is just above one of the straddling particles of lycopodium. The opposite lycopodium particle is seen only with difficulty. The lower arrow shows the end of the vessel within the heart muscle proper. The lycopodium particles (ingested) are well visualized here. Again fibrosis is scant in the lycopodium layer.

same size as the eosinophils (Fig 1). Close examination of this photograph will show the paucity of fibrous reaction.

Lycopodium powder can create a rather marked vascular reaction. Lycopodium is a very fine powder so fine that it seems to pour more like water than like a solid. It appears to be irritating enough to the tissues to cause adhesion formation with a rather marked vascular response and yet bland enough so that very little scar tissue is formed. Apparently the body does not attempt to encapsulate the lycopodium by laying down a fibrous tissue capsule about it. This is so not only when the lycopodium is packed closely together as in Figures 1 4 but also when it is very thin as in Figure 2. Grossly the vascularity created by lycopodium is easily seen with the naked eye. The normal rabbit pericardium is very thin and very few blood vessels can be seen in it. After lycopodium powder has been placed within the pericardial sac and adhesions are formed the vascularity is vastly increased.



Fig. 5. Photomicrograph of rabbit heart. This heart prepared by injection with India ink and bacteria described the rule. It shows blood vessel in the pericardium filled with ink and bacteria.

Blood vessels now become easily visible over the areas of adhesion. The fine vessels present in the normal pericardium become greatly dilated and the branching is greatly increased. This vascularity is easily demonstrated by



Fig. 6. Photomicrograph of rabbit heart. This heart as prepared by injection with India ink and bacteria as described. It is a section deep in the heart muscle. It shows a large vessel containing the black masses of India ink and bacteria. The endothelial lining of the vessel clearly seen.

section (Figs. 2, 3, 4). Newly formed blood vessels as evidenced by being surrounded by lycopodium granules or by going from the lycopodium layer into the myocardium are seen in many sections. In many cases the blood vessels are not just minute capillaries. Figures 2 and 3 show good sized vessels. Their diameter may be roughly estimated by counting the number of blood cells across any given plane. Figure 4 shows one vessel going into the myocardium from the lycopodium layer. In the lower half of the vessel its left wall was unfortunately narrowed during the sectioning process. The relative absence of fibrosis also is a favorable factor in the vascularity. This lack makes it highly improbable that subsequent scar contraction will constrict these newly formed blood vessels.

In order to demonstrate further the establishment of a collateral circulation to the myocardium from the pericardium a special technique was developed. About 6 to 8 weeks after the lycopodium had been placed within the pericardial cavity the rabbits were anesthetized and then given large doses of heparin intravenously to prevent clotting. Then with the animals still alive the abdominal aorta was cannulized (tip pointing toward the heart) and the cannula was connected to a faucet of tap water running in a steady stream. Stimu-



Fig. 7 Photomicrograph of rabbit's heart. This heart was prepared by injection with India ink and bacteria as described in the article. It is a section deep in the heart muscle. The large black mass in the lower left corner is a vessel filled with dye and bacteria and also has some red blood cells. Just to the right of this vessel is a small V-shaped vessel containing one glob of dye and bacteria. Above this vessel is a large vessel containing a small mass of dye and bacteria in its lowest portion.



Fig. 8 Photograph of rabbit's heart. This heart was prepared by injection with India ink and bacteria as described. It is a section deep in the heart muscle. It shows a large somewhat triangular vessel completely filled with ink and bacteria. Under the microscope red blood cells can be seen in this vessel. However because the dye which is used is so intense, the outlines of these cells can be made out only with difficulty in this photograph.

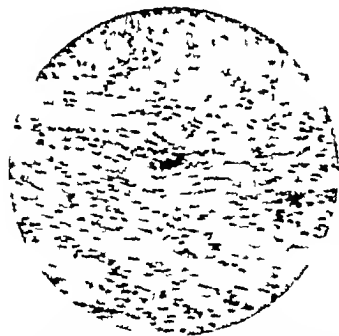


Fig. 9 Photomicrograph of rabbit's heart. This heart was prepared by injection with India ink and bacteria as described in the article. It is a section deep in the myocardium and shows a blood vessel containing ink and bacteria surrounded completely by heart muscle.



Fig. 10 Photomicrograph of rabbit's heart. This heart was prepared by injection with India ink and bacteria as described. It is a section deep in the heart muscle. In the center of the field is a thin vessel containing dye and bacteria.



Fig. 2. Photograph (enlarged) of opened heart of dog. The arrow on the far left points to the opened coronary orifice. The opened coronary artery continues in the direction of this arrow. On the right, the upper and lower arrows point to the cut ends of the silk tie that surrounds the common left coronary artery. The narrowing of the coronary artery can be seen just to the left of the point of ligation. The apparent branches coming from the coronary artery are created by dissection.

taneously a large opening was made in the inferior vena cava. By this method practically all the blood was washed out of the animal and the animal died within 15 minutes. Within a relatively short time almost pure water was coming out of the rent in the inferior vena cava. This washing out process was continued for 6 to 10 hours. Then the animal was placed in the icebox over night. In the morning the ascending aorta was clamped with three clamps and then cut between clamps just distal to the origin of the coronary arteries, but proximal to the origin of the carotids. The aorta was approached by resecting a rib or going through the neck. The abdominal aorta was injected with a heavy suspension of killed staphylococcus to which some filtered India ink had been added. Then the heart was removed, and sections were taken. It is obvious that with this technique of injection no ink or bacteria could reach the heart muscle through normal channels. Therefore no ink or bacteria could get into the coronary vessels. If any ink or bacteria appeared within the heart muscle it must, therefore, have reached there through the collateral circulation established with the pericardium. It could go from the intercostals, internal mammary phrenic, bronchial medil-

astinal to the pericardium. From here only newly formed blood vessels could carry it to the heart muscle proper. When pieces of heart muscle were cut out for sectioning small black specks were seen in the myocardium as well as in the pericardium. These gross observations were confirmed by microscopic sections (Figs. 5 6 7 8 9 10). Many sections of heart muscle seen under oil immersion showed minute capillaries containing 1 2 3 or more minute round black specks. We decided that it was not necessary to take photographs under oil immersion. However several good photographs were obtained showing India ink and bacteria within the myocardial vessels. The individual black specks cannot be seen in the accompanying illustrations with this magnification but they are nevertheless present.

Encouraged by the promising evidences of the experiments described, we took one dog into whose pericardial sac lycopodium had been placed. About 8 weeks later this dog was reoperated upon and 2 silk sutures were passed around the common left coronary artery and this artery was tied off. Then the main branches of this artery were also doubly tied. After operation this animal ran about ate and behaved normally in all respects. The day after operation when the dog was brought to the x ray department for an x ray of the chest to see if any pneumothorax was present (x ray film showed no pneumothorax) the dog jumped out of his box.

In a recent publication by Beck he stated that the common left coronary artery could not be ligated and have the dog live regardless of the method of preparation of the heart prior to ligation. However this can be done as proved by this instance. If lycopodium powder is used to prepare the heart. Ten weeks later this dog was killed, the aorta was opened, and the common left coronary artery was traced down to its point of ligation. Proximal to the ligation the vessel appeared dilated. Between the two closely placed ligatures was a minute brown clot which was trapped between the sutures. Distal to the ligature the vessel was found to be collapsed and contained a very thin threadlike white piece of tissue (Fig. 11).

SUMMARY AND CONCLUSIONS

The use of lycopodium powder placed with in the pericardial sac of 13 animals has consistently produced a very vascular adhesive pericarditis. Evidence demonstrating the vascularly lack of fibrosis and type of cellular reaction elicited by lycopodium is presented. A technique of injection with India ink and bacteria to show that collateral circulation to the myocardium has been established is described. Ligation of the common left coronary artery was not fatal to a dog

whose heart had been prepared with lycopodium powder

From these results we believe that lycopodium powder is an effective agent to produce a collateral circulation to the myocardium from the pericardium and warrants additional study

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ACUTE PANCREATITIS WITH SPECIAL REFERENCE TO X RAY DIAGNOSIS

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BETWEEN the years 1931 and 1933 27 patients in whom a diagnosis of acute pancreatitis was established were admitted to the King County Hospital, Seattle. The diagnoses were proved either at operation or autopsy. There were 10 patients with acute pancreatic edema, 9 of whom were operated upon and survived. The other patient was treated for bronchopneumonia and died. The postmortem examination revealed acute pancreatic edema. There were 17 patients with acute pancreatic necrosis, 9 of whom came to postmortem examination with out benefit of surgery. 5 had previous surgery and 3 were operated upon and survived. We are also including 5 other cases in which we consider the diagnosis to be proved by the blood amylase and other typical findings and by the x ray films.

The roentgen findings suggestive of acute pancreatitis have already been given in the literature. They are essentially only three: (1) tender tumefaction of the pancreas, found during fluoroscopy and the most valuable finding as it is pathognomonic; (2) changes in the stomach and duodenum; (3) evidence of localized or generalized ileus.

The changes in the stomach and evidences of localized ileus can easily be seen not only by a radiologist but by any surgeon who knows what to look for. The changes are predicated upon the fact that the pancreas in acute disease is swollen to two or three times its normal size. It presses against the greater curvature of the stomach as can be seen in Figures 1 and 2. The duodenum shows ileus, it has lost its tone, and the fluoroscopist will be able to push barium into it where it seems to hang and fails to be moved forward by peristalsis. The duodenal loop is also enlarged (Figs. 1 and 2).

These changes can often be suspected in a plain scout film with the patient supine. Oc-

casionally there will be enough gas in the stomach to give the characteristic outline (Figs. 3, 4, and 5) of the greater curvature near the pylorus. More frequently there will show a fair sized blob of gas in the cardia and another smaller one in the duodenal bulb (Fig. 6). This is a very characteristic finding. Increased density of the pancreatic area may be observed (Figs. 3, 4, and 5). Also localized ileus, especially of the transverse colon or upper loops of jejunum is observed (Figs. 3, 4, and 5). This is undoubtedly because the early pancreatic enzymes are starting to escape along the transverse mesocolon and root of the mesentery. Later generalized peritonitis sets in and the picture of generalized ileus complicates the scout film.

These x ray findings were present when the patients were first seen and persisted as long as the disease lasted—in 1 case, 21 days after onset—and long after the blood amylase had returned to normal.

However not all impingements upon the greater curvature of the stomach are due to the pancreas. In 1 case (Fig. 7) the preoperative diagnosis was cyst of the pancreas and the postoperative diagnosis was carcinoma of the gall bladder. The x ray findings must be correlated with the clinical picture. Figure 8 shows the typical deformity of a pancreatic cyst.

Every one of our 32 cases had a sudden acute onset with nausea and vomiting. They had epigastric pain and when seen early had no fever, a normal blood pressure, and slow pulse. Tenderness was often so slight as not to be noticed by the examining internist.

Curiously every patient had albuminuria from a trace to 3 per cent. Fatty degeneration of the kidney was found on 1 postmortem examination. We wonder if the blood and urine amylase could be related to these phenomena. While albuminuria is so common



Fig. 1. E. D., No. 121,621, male, aged 61 years. Admitted with acute upper abdomen of 24 hours' duration. Blood amylase was 356 and 2 days later was 16. Examination of stomach 5 days later shows elevation of stomach at duodenojejunal junction, flattening of greater curvature of stomach, and increased size of duodenal loop.



Fig. 2. E. S., No. 45,240, male, aged 66 years. Roentgenogram which was made 3 weeks after onset. Note narrowing of the pylorus, flattening of the greater curvature of the stomach, elevation of the stomach with reference to the duodenojejunal junction and some increase in size of the duodenal loop.



Fig. 3. L. D., No. 170,759, female, aged 65 years. Film made 24 hours after acute onset. Note elevation and flattening of greater curvature of stomach, increased space between greater curvature and transverse colon and increased density in pancreatic area. Localized ileus in stomach, duodenal bulb, transverse colon, and a few loops of small bowel.



Fig. 4. H. Z., No. 168,500, female, aged 28 years. Film made 20 hours after acute onset. Note elevation and flattening of greater curvature of stomach, increased density and increased space between greater curvature of stomach and transverse colon. There are areas of localized ileus of stomach, duodenal bulb, and transverse colon.



Fig. 5. F M., No. 144,757 female, aged 57 years. Film made 3 days after onset. Note flattening of greater curvature of stomach, elevation of stomach, increased density in the pancreatic area, increased space between greater curvature of stomach and transverse colon, areas of local tenderness of stomach, duodenal bulb, transverse colon, and



loops of small bowel. This patient also developed fluid in the left chest. (Pancreatic necrosis.)

Fig. 6, above. F P. No. 35,074, male, aged 66 years. Acute pancreatitis showing collection of air in cardia of stomach, duodenal bulb, and scattered areas in small and large bowels especially in upper half of abdomen.

as to be of no diagnostic significance the absence of albuminuria would apparently throw doubt on the diagnosis of pancreatitis.

In general these patients might suggest a ruptured peptic ulcer but they lacked the board-like rigidity. They might suggest an acute gall bladder except for the fact that they were too ill or an acute coronary thrombosis but for the slow or normal pulse rate and blood pressure. Certain types of strangulated obstruction might make differential diagnosis difficult as acute pancreatitis must also be accompanied by a silent abdomen. Unfortunately in the 37 histories a note on abdominal auscultation was made only once.

The patients with pancreatic necrosis were sicker than those with pancreatic edema. Their white blood count averaged 16,000 against

12,000 and the polymorphonuclear count averaged 85 to 90 per cent against 75 to 80 per cent. However 1 patient with necrosis who survived for 21 days developed leucopenia. In our 17 cases of necrosis cyanosis was noted 10 times, distention 9, rigidity and tenderness 4 times. Glycosuria was present 4 times and postmortem examination showed marked destruction of the pancreas in 4 cases. Jaundice was present only twice and in those instances it was associated with stone in the common duct.

In the edema cases, the blood amylase remained high as long as the disease lasted, 18 days in 1 case. In the necrosis cases the blood amylase returned to normal in about 2 days, although in 1 case x ray findings persisted for 21 days.



Fig. 7



Fig. 8.



Fig. 9.



Fig. 10.



Fig. 11.

Fig. 7. M. M. No. 174,299, female, aged 66 years. Enlargement of the duodenal loop by a carcinoma of the gall bladder the pressure on the duodenum being from anterior.

Fig. 8. A. D. P. No. 26,430, male, aged 48 years. Typical deformity of pancreatic cyst showing upward concavity of pylorus and enlarged duodenal loop.

Fig. 9. C. L., No. 68,631, female, aged 18 years. Film made 25 hours after acute onset showing collection of air in cardiac portion of stomach, and a few areas of localized ileus.

Fig. 10. Same case as Fig. 9. Examination of stomach made 43 hours after onset showing flattening of the greater curvature and elevation of stomach as compared with Fig. 11. Fluoroscopically a marked tenderness and resistance was present in pancreatic area and also a marked stasis in the passage of the barium through the duodenum was noted.

Fig. 11. Re-examination of the stomach 13 days after onset at which time no abnormal findings were present.

Nine patients with pancreatic edema were operated upon and 9 survived. The operations were as follows: 1 cholecystectomy, 1 cholecystostomy, 1 choledochostomy, 2 cholecystectomies and choledochostomies, 3 explorations and closures, and 1 gastroenterostomy.

Eight patients with pancreatic necrosis were operated upon. Five died and 3 survived. The operations on the 5 who died were: 1 cholecystectomy, 2 cholecystostomies, 1 gastroenterostomy and 1 exploration and closure. Of the 3 who survived 1 had a cholecystectomy.

1 an exploration and closure and 1 had a cholecystostomy and drainage of the lesser peritoneal cavity.

If an unbiased observer were to forget that most of these operations turned out to be diagnostic surprises to the operator he might reasonably conclude that the surgical attack lacked unity to say the least. Survival seems to depend on the benignity of the disease more than upon the surgical procedures employed. We believe that the acute phase of this disease is best treated by nonoperative means. We have thought x ray therapy in small doses may be indicated.

While studying these cases a 20 year old girl was brought to the accident ward at night 26 hours after a catastrophic onset of epigastric pain. Her pulse was 140, blood pressure 112/70. She had nausea and vomiting. There was no rigidity, slight tenderness, and a silent abdomen. The leucocyte count was 20,000 with 93 per cent polymorphonuclear leucocytes. She looked almost moribund and the resident suspected acute pancreatic necrosis. He took blood for a blood amylase test and the result was 121 units against a normal of 8. The flat plate of the abdomen (Fig. 9) taken that night showed no other cause for her trouble. In addition it shows the blob of air under the left diaphragm, a slight amount in the

duodenal bulb and a few areas of localized ileus.

She was treated with continuous gastric suction, sedation and intravenous fluids. She did not seem much better when taken to the x ray department the next morning. The film shows the flat bottom stomach (Fig. 10). Considerable time was spent in fluoroscopy at which time a tender tumefaction with upward displacement of the stomach was found. A small therapeutic roentgen dose was received by the patient during this time. She made very rapid improvement and was almost well the next day. Eleven days after the onset the roentgen examination showed the loss of the flat bottom of the stomach (Fig. 11) and 3 days later a gall bladder filled with stones, 3 stones from the common duct, and 7 from the hepatic duct were removed. The pancreas at the time of operation was found to be slightly indurated on palpation but no enlargement was noted.

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TRANSMESENTERIC HERNIA

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IN 1923, one of us (G.D.C.) published a paper on mesenteric defects as a cause of intestinal obstruction reporting 2 cases from the Surgical Service of The Children's Hospital and tabulating data on 26 additional cases of this condition collected from the literature. Recently 2 more patients with transmesenteric hernia have been successfully treated in this clinic and our interest in the subject has been renewed. We have assembled 46 well documented cases from the literature permitting a survey of 50 cases of hernia into apertures in the mesentery.

CASE REPORTS

CASE 1. R. B. C. H. No. 233661, a 6½ year old white boy was admitted to the hospital on August 19, 1939, with a complaint of abdominal pain and vomiting of 15 hours duration. Family history and past history were irrelevant excepting one admission to the hospital 8 months previously because of abdominal pain without vomiting of 1 day's duration. At that time symptoms rapidly disappeared and physical examination was negative. Consequently he had been discharged home the following day without operation.

The present episode began with the child awakening on the morning of admission with severe abdominal pain centered about the umbilicus. He vomited shortly thereafter and during the course of the day had persistent vomiting every 20 to 30 minutes totalling about twenty times. The pain was described as diffusely periumbilical and constant with crampy exacerbations which caused him to double up and scream. A normal bowel movement without blood occurred shortly after the onset of symptoms but after this there was passage of neither feces nor flatus by rectum.

Physical examination on admission showed an acutely ill, dehydrated child with temperature 38.6 degrees, pulse 120, respirations 24, and blood pressure 100/65. The heart and lungs were normal. The abdomen was diffusely tender over both lower quadrants without spasm. There was a questionable mass in the right lower quadrant. Peristalsis was diminished. Genitalia, rectal examination, reflexes and extremities were negative.

Laboratory findings on admission: white blood count was 32,500 with 90 per cent polymorphonuclear cells. Urine was negative except for ++++

acetone. Stool (finger specimen) showed no occult blood.

After admission the child was given an intravenous infusion of 5 per cent glucose in saline following which laparotomy was carried out, under nitrous oxide and oxygen and ether anesthesia, by Dr. T. W. Botsford. Coils of gangrenous bowel presented when the peritoneum was opened and a large quantity of foul smelling sero sanguineous fluid escaped. There was a 1 by 2 centimeter defect in the ileocecal mesentery through which a loop of about 6 inches of terminal ileum was strangulated with a 360 degree volvulus of the afferent and efferent limbs. Approximately 18 inches of terminal ileum with its adjacent mesentery was black in color dull and friable but not perforated. Resection of the 18 inches of gangrenous ileum and attached mesentery together with the appendix and cecum was carried out and a primary lateral anastomosis between the ileum and ascending colon was constructed. The abdomen was then rapidly closed in layers without drainage.

After operation the child was maintained on Wangenstein siphonage and parenteral fluids for 48 hours following which he took fluids well by mouth and had a spontaneous bowel movement on the fourth postoperative day. Postoperative course was complicated by the development of a pelvic abscess which resorbed spontaneously with hot rectal irrigations. The child was discharged home on an unrestricted diet on the 28th postoperative day. He has been followed in the outpatient department for 4 years and has had no further difficulties whatsoever.

The specimen consisted of 40 centimeters of gangrenous terminal ileum with the cecum and appendix. There was a 1 by 1.75 centimeter defect in the mesentery close to the attachment of the bowel and 8 centimeters from the ileocecal junction. The defect was oval in shape with a smooth thickened margin.

CASE 2. J. S. C. H. No. 275668, a 21 month old white girl was admitted to the hospital on August 27, 1933 with a 16 hour story of crampy abdominal pain and vomiting. Family history and past history were noncontributory.

The child had been entirely well until about 23 hours prior to admission when she was thought to have swallowed a plum pit. This apparently occasioned no difficulty until 16 hours before entrance when she developed sudden severe abdominal pain which caused her to double up and scream. Shortly thereafter she vomited. The pain persisted occurring in waves every 15 to 20 minutes. During the course of the day the child vomited eight or nine times and remained extremely fretful and irritable. Normal bowel movement occurred the day before

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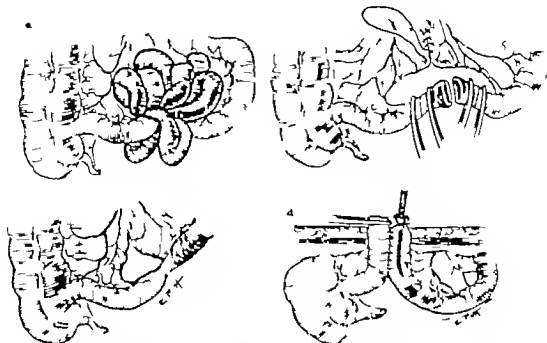


Fig. 1. a, Appearance of strangulated transverse hernia with volvulus and gangrenous loop. b, Volvulus reduced followed by reduction of hernia with splitting of margin of hernial ring. c and d, Steps in Milikowsky resection of gangrenous bowel.

and two enemas were given after the onset of pain with scanty fecal and no flatal returns. The vomitus became progressively more fecal in character and after arrival at the hospital consisted of coffee ground material streaked with dark blood which showed + + + + guaiac test. The child had grown increasingly fatigued and drowsy during the course of the day between the onset of pain.

Physical examination on admission showed an almost moribund child with marked pallor and lassitude. Temperature was 99 degrees, pulse 44, blood pressure 60/30. Heart and lungs were normal. The abdomen was diffusely tender. There was slight epigastric distention without patterning. No palpable mass could be made out and there was no true muscle spasm. Peristalsis was absent. Genitalia, reflexes, and extremities were negative. On rectal examination there was light tenderness high in the pelvis. No feces or blood were present in the rectum.

Laboratory findings on admission. White blood count was 9,000 with 80 per cent polymorphonuclears. Red cell count was 4,500,000. Urine was negative except for + + acetone. Vomitus was coffee ground in appearance and gave a + + + + guaiac reaction. Stool specimen was not obtained.

Röntgen series films of the abdomen were taken immediately after admission. With the patient in the upright position these showed a few dilated loops of small bowel with fluid levels. The child was given

an intravenous infusion of 5 per cent glucose in saline and a laparotomy was performed within 2 hours after admission. Preoperative diagnoses were acute intestinal obstruction, question of small bowel intussusception, and question of volvulus.

Operation was performed by Dr. G. D. C. Under ether anesthesia a long right rectus muscle splitting incision was made and when the peritoneum was opened there was gush of dark colored foul smelling and serosanguineous fluid. Coils of jet black gangrenous bowel presented and exploration revealed these to consist of about 3 feet of distal ileum. There was a transverse herniation of a loop of about 25 centimeters of ileum through a 5 centimeter defect in the mesentery situated about 8 to 10 centimeters from the ileocecal junction. The proximal and distal limbs of the strangulated bowel had undergone a 750 degree volvulus, so that a total of about 3 feet of bowel was gangrenous. There was no free perforation. The margin of the mesenteric hiatus was first incised and the herniated loop extracted following which the volvulus was reduced. Milikowsky resection of the gangrenous ileum was then carried out. After closure of the abdomen in layers the double-barreled ileostomy the exteriorized gangrenous bowel was excised with the cautery. A catheter was inserted into the proximal limb for drainage and a clamp was left on the distal limb for support. During the course of the procedure the child's pulse rate rose to 200, and blood pressure fell



Fig. 2. J. S. Flat and upright roentgenograms of abdomen in patient with transmesenteric hernia.

to zero. Two hundred and fifty cubic centimeters of plasma was given intravenously with rapid improvement and at the close of the operation the pulse was 170 and the blood pressure 100/55.

After operation the child was maintained in high concentration oxygen on Wangenstein suction and parenteral fluids with blood and plasma for 24 hours. The ileostomy functioned well and there was no distention. After the second postoperative day she took fluids well by mouth and was started on a low residue diet on the 4th postoperative day. Her chart remained flat and her general condition good. Fourteen days after operation the spur was crushed and operative closure of the ileostomy was attempted a week later. A fecal fistula persisted however, but closed gradually of its own accord and the child was discharged home after 44 days in the hospital. She has been followed for 5 months in the

outpatient department and has had no difficulties. Bowels move twice daily. The wound is solidly healed and the child has gained 5 to 6 pounds in weight.

The pathological specimen consisted of 105 centimeters of gangrenous small intestine. In the mesentery there was defect circular in shape with thickened smooth edges. This defect measures 1.5 centimeters.

Textbooks of surgery give but cursory mention of transmesenteric hernia and the literature on the subject is largely in the form of



Fig. 3. J. S. View of the mesenteric defect enlarged by incision for reduction of hernia.

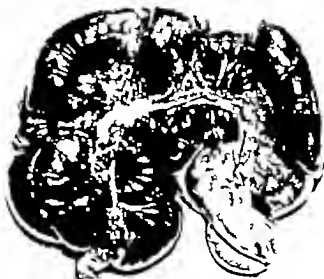


Fig. 4. J. S. Pathologic specimen of gangrenous bowel resected.

isolated case reports. The entire subject of intra-abdominal hernia was reviewed by Hansmann and Morton in 1939. These authors classified 467 reported cases of internal hernia according to the site of the hernial orifice and found 52 cases of transmesenteric hernia, 14 of which had openings in the ileocecal mesentery and 38 were found to have apertures located at higher levels in the small bowel mesentery. According to their statistics, transmesenteric hernia apparently constitutes about 11 per cent of all intra-abdominal hernias.

In general intra-abdominal hernias are relatively uncommon causes of acute intestinal obstruction. McIver found in 335 cases of acute intestinal obstruction only 3 cases of internal hernia (0.9 per cent). Hence transmesenteric hernias are among the least common causes of acute intestinal obstruction.

In this series of 50 cases, there were 30 males and 21 females. The youngest patient was 4 days and the oldest 73 years. The condition is fairly evenly distributed throughout early, middle and late life.

Transmesenteric hernias are intraperitoneal hernias which have no sac but consist in the protrusion of a knuckle or loop of bowel through an aperture in the mesentery which may lead to intestinal obstruction and strangulation and subsequently to gangrene of varying lengths of intestine. This type of hernia is analogous to herniation through defects in the omentum and the broad ligament and differs from the other forms of intra-abdominal hernia in which the loops of bowel are incarcerated in an enveloping sac of peritoneum or peritoneal reflexion.

Holes in the mesentery were not infrequently described by the early anatomists and pathologists. Mitchell states that these defects are met with about once in every 400 cadavers. According to Watson (48) mesenteric defects were found in 3 of 1600 autopsies—in each case the aperture was in the mesentery of the ileocecal junction.

In the 50 cases under consideration defects were present in the mesentery of the ileocecal junction in 35 instances; in 6 individuals the openings were located at the midileum and in 2 in the jejunal mesentery. One patient

had a defect in the mesosigmoid and in 4 others there were multiple fenestrations at the entire length of the mesentery. In 5 the exact site of the mesenteric aperture was not given in the report.

In the majority of instances the apertures were quite small, averaging only 2 to 3 centimeters in diameter. In a few cases they were larger, the largest being 10 to 15 centimeters in diameter. They were usually circular or oval in shape with smooth peritoneal edges. In Brown's case the opening was slit like with rough, irregular edges.

There are several theories as to the etiology of defects in the mesentery.

Trauma, inflammation with subsequent atrophy and developmental or congenital causes are supported by various authors. The traumatic theory was advocated by Brown. In his case symptoms were preceded by a heavy fall and at operation the defect in the mesentery was slit like with rough edges and resembled a laceration. A history of a fall, a blow on the abdomen or similar trauma preceding symptoms of acute obstruction was present in only 8 of the 50 cases under discussion. Nevertheless in these 8 individuals the mesenteric aperture was described as circular and smooth and apparently of long standing except in Brown's patient. Cases in which hernia was associated with a previous surgical operation are not included in this series.

Inflammation is thought to be the cause of the defects by Hohlbaum, Prutz, and King. King is of the opinion that appendicitis explains the high incidence of occurrence in the ileocecal region. In his case there was acute appendicitis with the appendiceal tip adherent to a knuckle of ileum which had prolapsed through a defect in the mesentery, the latter having smooth rounded edges. No other cases in the present series had histories of previous attacks of acute appendicitis or peritonitis. We were unable to find any specific instances in the literature on peritonitis of the development of holes in the mesentery. Consequently this hypothesis seems to be lacking in proof.

Popovschek described a patient with tuberculous of the ileum and cecum involving the

adjacent mesentery in which transmesenteric herniation of bowel took place through a defect in the involved segment of mesentery. In this instance inflammatory changes did seem to account for the mesenteric defect.

Most authors have felt that the mesenteric holes have a developmental etiology. Feder Schmidt believed that the defects represent an atavistic regression of the dorsal mesentery—a progression of the changes which cause the disappearance of the primitive ventral mesentery. Long reported a case in which multiple mesenteric fenestrations were present with herniation of bowel through one of the defects. This recalls the fact that multiple fenestrations of this type are common in the mesentery of the goose, possibly lending some support to Feder Schmidt's hypothesis.

Treves described an anatomical explanation for mesenteric defects which was further supported by Hommes. According to the former there is an avascular area in the mesentery of the ileocecal region circumscribed by the anastomosis between the ileocolic artery and the last intestinal artery supplying the terminal ileum. The mesentery in this region is poorly supported and contains neither fat, lymph nodes nor visible blood vessels. It was here that he found defects in studying cadavers. Hommes reported 2 cases with defects in this region in which there was no true ileocolic artery but rather a strongly developed right colic artery which anastomosed with an enlarged terminal intestinal vessel named by Hommes the *arteria ilei magna*. This anastomosis enclosed an avascular field in the center of which lay the hole in the mesentery.

Macklin in studying the development of the alveolar spaces in the lung has pointed out that when two layers of epithelium are opposed—base to base—with a deficient intervening supporting stroma of connective tissue coalescence inevitably takes place with the development of a space or a hole.

The clinical occurrence of the great majority of mesenteric defects in the ileocecal region adds considerable support to the ideas of Treves and Hommes. Possibly there is in addition pressure on this avascular area by the rotation of the cecum in early embryonic life (23) or stress exerted by the protrusion of

the midgut into the umbilical coelom. Coalescence of the mesothelium in an avascular area during embryonic life is equally applicable in explanation of the mesenteric defects occurring higher in the mesentery but specific anatomical descriptions are lacking. From the descriptions of the character of the defect in this series of 50 cases they obviously (with the exception of Brown's case) are not of recent origin. These facts plus their occurrence in early infancy seem to indicate that the majority of the defects are of developmental origin while a few may occur with inflammatory changes and following trauma.

The mechanism whereby a loop of bowel becomes incarcerated in a mesenteric defect constitutes an interesting problem. Certainly there is no possible pressure gradient as in the case of external hernias. It is probable that with the accidental prolapse of a knuckle of bowel through the ring like opening distention results in a gas trap mechanism and this is the force that draws loops of bowel through the aperture until incarceration occurs. This has been shown experimentally by the work of Gatch, Trusler and Ayers. Thus the size of the hole does not limit the length of prolapsed bowel. In fact in Brown's case the entire small intestine had passed through a mesenteric defect about 3 inches in diameter.

Once incarceration takes place the familiar changes of intestinal strangulation leading to gangrene develop with the coincident clinical symptoms and signs of acute intestinal obstruction. The terminal ileum is most commonly the segment of bowel herniated through the defect. In A. M. Smith's case (41) the sigmoid passed through an ileocecal defect and carried with it the adjacent segment of ileum.

Gangrene may supervene extremely rapidly. In 62 per cent of this series (31 cases) gangrenous bowel was encountered with duration of clinical symptoms varying between 6 hours and 11 days. The shortest duration of symptoms with gangrene found at operation was 6 hours (Williamson's case).

Volvulus of the strangulated loop of bowel was present in 9 cases. In the last 2 patients operated upon at The Children's Hospital volvulus of the afferent and efferent limbs of

the strangulated loop had occurred adding to the extent of gangrene. The proximal and distal limbs of the involved loop were twisted about one another at the point of herniation through the mesentery forming a veritable Gordian knot. The volvulus is probably the result of hyperactive peristaltic rushes, occurring after incarceration has taken place.

The clinical picture of transmesenteric hernia is that of acute intestinal obstruction occurring abruptly with the onset of severe crampy abdominal pain followed by vomiting and associated with complete obstipation. The onset of shock seems to vary inversely in proportion to the length of intestine strangulated. The onset of gangrene was accompanied in almost every case by profound shock.

On physical examination these patients inevitably appeared to be severely ill. In every case there was abdominal tenderness which was most frequently right sided but occasionally diffuse and accompanied by varying degrees of distention and peristaltic patterning. Peristalsis was obstructive in type in most cases but with the onset of gangrene auscultation usually revealed a silent abdomen. In several of the other cases with extensive transmesenteric herniation and in many of those complicated by volvulus, a palpable abdominal mass was present.

Laboratory findings were essentially those of acute intestinal obstruction with varying degrees of hemoconcentration and leucocytosis and were not usually very helpful in diagnosis. In our last case (J.S.) the leucocyte count was only 10,000 despite the presence of 105 centimeters of gangrenous bowel.

Röntgenographic studies of the abdomen have shown evidence of mechanical small bowel obstruction but nothing to suggest the exact nature of the obstruction.

The specific diagnosis was never made correctly before laparotomy in any of these cases and there is little to suggest that transmesenteric hernia can be accurately differentiated from acute intestinal obstruction associated with bands, volvulus, attached Meckel's diverticulum, vitelline vein remnant or some of the other forms of internal hernias. In several cases the preoperative diagnosis was

acute appendicitis, but most patients were recognized as having acute intestinal obstruction.

Treatment has consisted of reduction of the hernia or resection, depending on the state of the bowel. In this series there were 19 reductions and 22 resections. In 4 instances laparotomy only was performed while 5 patients were not explored and the cause of death was discovered at autopsy. The total mortality of these 50 patients was 38 per cent. The mortality in those cases in which reduction was possible was 15.7 per cent. In 22 patients with gangrenous bowel necessitating resection the mortality was 31.8 per cent. In 17 cases in which resection was done primary anastomoses were carried out with a mortality of 35.3 per cent. In only 5 cases Mikulicz resection was performed with a 20 per cent mortality.

When the incarcerated bowel is nonviable and gangrenous it is our opinion that the Mikulicz resection offers the patient the optimum chance of survival. This procedure can be performed rapidly with a minimum of operative trauma. It possesses the combined advantages of aseptic resection and immediate decompression of the obstructed bowel.

If the bowel is viable and nongangrenous, then reduction of the hernia can usually be facilitated by incising the margin of the defect in an avascular area. Obviously the mesenteric aperture should always be closed after reduction to avoid recurrence of hernia.

SUMMARY

1. Two cases of transmesenteric hernia are added to 2 previously reported cases from the Children's Hospital and data on 46 well documented cases from the literature are reviewed and analyzed.

2. Transmesenteric hernia comprises about 11 per cent of all intra abdominal hernias and is among the least common causes of acute intestinal obstruction.

3. The majority of mesenteric defects are of developmental origin while a few may result from inflammatory changes and following trauma.

4. The clinical picture is that of mechanical small bowel obstruction and an accurate

preoperative diagnosis has never been made

5 Treatment is early laparotomy with reduction or resection depending on the state of the bowel. When gangrene is present, Mikulicz resection is the procedure of choice.

6 The total mortality of these 50 cases was 38 per cent. Three of the 4 patients treated at the Children's Hospital have recovered.

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THE RÔLE OF THE NUCLEUS PULPOSUS IN THE PATHOGENESIS OF SO CALLED RECOIL INJURIES OF THE SPINAL CORD

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IN the condition known as recoil injury the spinal cord may be severely damaged without demonstrable or commensurate injury to the spinal column. Driving accidents, or certain automobile accidents in which the head is whip-lashed forward producing a forceful anterior flexion of the cervical spine are the usual causes. Less frequently extreme retroflexion may cause similar lesions. This is commonly stated and believed to be due to the sudden massive dislocation of a vertebral body which then recoils by reflex contraction of the antagonist muscles. This explanation has been employed for a number of years and is rather generally repeated in the books and literature on the subject, but it appears to have been arrived at on purely theoretical grounds and on negative observations.

In this case presentation it is our purpose to give what we believe to be an essentially new concept in the pathogenesis of the spinal cord lesions, replacing that heretofore held. On the basis of our observations and findings we believe that it is not the rather incredible excursion of a vertebral body virtually across the width of the spinal canal and back again but rather it is the violent protrusion of the intervertebral disc by means of the hydraulic ram-like action of the nucleus pulposus, or the rupture of the latter when subjected to sudden intense compressive force which causes the damage to the spinal cord.

CASE PRESENTATION

A 30 year old soldier was admitted to hospital on July 23, 1943 with the following history:

At about 1:00 a.m. that day he dived into shallow water in a dam, striking his head, and becoming dazed momentarily. He was removed from the water

by others and was found to have a paralysis of all four extremities, with numbness below the nipples. A medical officer saw the patient shortly after the accident and he was transported to a general hospital. During the trip to the hospital the patient observed that he was able to flex his arms; he also experienced spontaneous pains in the arms.

Examination revealed the following positive findings: complete paralysis below the 5th cervical segment. Breathing was abdominal in type, the chest movements being paralyzed. Except for the biceps tendon reflexes, all deep reflexes were abolished. Except for the plantar responses, all superficial reflexes were absent. Priapism was present. He was unable to void urine voluntarily. Temperature was 102 degrees, respirations, 30.

X-ray films of the cervical spine were taken in lateral view and showed a very slight compression fracture of the anterior portion of the body of the 5th cervical vertebra as well as a slight narrowing of the posterior portion of the 4th intervertebral space (Fig. 1).

An orthopedic and neurological consultation was held and it was decided to apply skeletal traction, even though the deformity in the spine was slight. There was no evidence of any displacement of the posterior elements of the spinal column and therefore no indication for laminectomy. Skeletal traction was obtained by the application of the Crutchfield skull tongs.

His condition remained stationary for the next 36 hours, and he was rational and comfortable. At 9:00 a.m., July 25, 1943 he was found to be suffering respiratory distress, with cyanosis and abnormal moisture in the respiratory passages. Intranasal oxygen therapy with carbon dioxide was administered, and coramine was given twice. As the morning progressed, he became more somnolent and finally lapsed into coma, expiring about 2:00 p.m., July 5, 1943, 30 hours after the accident.

At autopsy the following pathologic diagnoses were made: respiratory system—pulmonary edema, severe, acute, bilateral; spleen and hematopoietic tissues—splenic enlargement, chronic, cause undetermined; bones and joints—(a) fracture of body and arch of 5th cervical vertebra, simple, occurred in same accident, and (b) prolapse of intervertebral disc between 4th and 5th cervical vertebrae, acute, traumatic.

The autopsy protocol read: brain—no pathology on external examination or cut sections through the

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pons and medulla. Sectioning after proper fixation showed no pathological changes spinal column and spinal cord—small hematomas were noted in the margin of the dorsal process of the 5th and 6th cervical vertebrae and around the epistropheus. A small splinter of bone was found on the left side of the vertebral arch of the 5th vertebra exteriorly. Opposite the 5th intervertebral space, the spinal cord was practically severed except for the posterior columns and the posterior portion of the pia. At the 5th cervical interspace there was a sharp protrusion of the intervertebral disc, opposite the site of the spinal cord lesion. On inspection, the posterior diameter of this disc was about twice that of either of the adjacent disc spaces and the projection into the spinal canal measured about 4 millimeters. The adjacent periosteum and ligaments showed some hemorrhage.

The spinal cord was almost severed. Aside from the prolapse of the intervertebral disc, no abnormal vertebral protrusion nor gross tearing of any posterior ligaments could be demonstrated at autopsy. The case is cited as an example of laceration of the spinal cord by sudden severe traumatic prolapse of the intervertebral disc by the projectile force of the compressed nucleus pulposus. There was no roentgen evidence of dislocation of the vertebral body nor could manual and instrumental manipulation demonstrate any abnormal mobility of the bodies of the cervical vertebrae when the cervical canal was exposed. The spinal cord and the prolapsed portion of the disc were obtained as specimens (Fig 2).

REVIEW OF LITERATURE

It is of interest that the literature contains descriptions and photographs of somewhat similar cases showing herniations of the nucleus pulposus yet in explaining the mechanism of injury to the cord all authors hew to the old line of reasoning of dislocation with recoil.

Courville states. The radiographic evidence of injury to the spine is extremely variable. Instances of complete transection of the cord may show no evidence of either fracture or dislocation. The dislocated vertebra responsible for the injury springing back into place after the traumatizing force has been expended.

Clark cites the case of a patient with complete and immediate paralysis who is still living after 8 years still paralyzed from the neck



Fig 1. Roentgenogram of cervical spine, Case 1. Arrow indicates point of compression fracture, anterior surface, 5th cervical vertebra.

down. He showed only a mild compression of the 6th cervical vertebra in the roentgenogram. Clark rationalizes that the damage to the cord may have been caused by a dislocation which reduced itself spontaneously.

Scudder cites a case in which death resulted from skull injury in which the spinal cord was crushed. He describes it as dislocation spontaneously reduced of the 6th on the 7th dorsal vertebra. There is complete rupture of all hindling ligaments and the disc is shattered. There can be found no fracture or dislocation of the vertebrae. A large fragment of disc tissue and



Fig. 2. a, Section of spinal cord, Case 1. Anterior surface showing incomplete severance. b, Prolapsed portion of 5th intervertebral disc.

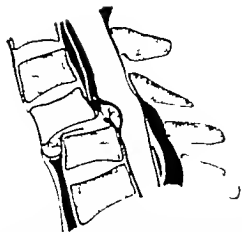


Fig. 3. Drawing from portion of photograph in Pancoast (loc. cit.). Specimen of spinal cord of patient drowned in diving accident. Fifth cervical vertebra and some of its processes are partially crushed. The spinal cord compression is caused directly by the posterior herniation of the nucleus pulposus, and not by the vertebral body.

a collection of blood clot are lodged between the dura and the posterior wall of the vertebra above. This mass presses upon the crushed cord. Marked dislocation of the vertebra above must have occurred momentarily, replacement having taken place through the recoil of the column when the force was spent. (The illustration accompanying the text in the book shows the contents of the intervertebral disc extruded upward into the canal, opposite the lower half of the vertebra above. It is at this point that the cord is crushed. Granted that there was a certain marked degree of dislocation at the time of the accident and that the ligaments were torn, it nevertheless appears logical that the spinal cord was crushed by the violently extruded disc rather than by the temporary dislocation of the vertebral body.)

Watson Jones, in discussing cervical dislocation states: "The most severe degrees of primary bony displacement may be masked by complete spontaneous reduction. In some cases there is no radiographic evidence of bone injury at all, and yet the cord is irreversibly damaged. He states that free mobility of the dislocated segment of the spine depends upon tearing of the ligaments of the interarticular and intervertebral joints. Pancoast, Pendergrass and Shaeffer illustrate this subject excellently with a case of partial fracture-disloca-

tion of the 5th cervical vertebra and resultant compression of the spinal cord in a diving accident. Figure 3, which was drawn upon a tracing from their photographic illustration, shows clearly that the ligaments of the 4th intervertebral space have ruptured and the contents of the disc have herniated both anteriorly and posteriorly, the latter mass compressing the spinal cord. It is noteworthy in viewing this case that although the dislocation of the 5th vertebral body is considerable, this in itself would have caused little or no impingement upon the cord if the disc had remained intact. These authors corroborate this observation by the following discussion: "In the cervical region the severity of the trauma to the spine bears little relation to the cord injury. Often there is comparatively little roentgenographic evidence of traumatism to the spine with the most severe cord injuries. On the other hand there may be a serious fracture with permanent dislocation and marked displacement and little or no cord disturbance. It is evident therefore that the seriousness of the injury depends entirely on the damage present and remote to the cord and nerve tissues. If for the sake of argument one granted that the static posttraumatic dislocation was no criterion of the amount of displacement which occurred at the moment of greatest stress and strain, this case nevertheless proves that it is the herniation of the nucleus pulposus and cartilage which has produced the injury to the cord."

Davis has shown by experiment with a testing machine, that the anterior longitudinal ligament shows no evidence of stretch and that the average breaking point is at 337 pounds (153 kgm).

An extensive search of the literature by Stinchfield revealed that the writers on the subject considered that the ligaments of the vertebral column are relatively stronger than the bones and that the latter are more apt to fracture under stress than the ligaments are to rupture.

THE TRUE MECHANISM PRODUCING SPINAL CORD INJURIES

The pathologic proof presented in our case and in those others in which there was autopsy

material all points incontrovertibly to the injured intervertebral disc as the agent traumatizing the cord. The credibility of the accepted but factually ungrounded theory is further controverted by reasoning on the facts of the anatomy and function of the vertebral joints and ligaments.

This construction is such that a dislocation occurring under great stress must inevitably be associated with tearing of the ligaments or fracture of the bones or both. Normal motion is so circumscribed that the degree of motion and the arcs which the vertebrae will describe in moving in various directions is actually stereotyped at each segment and for each region.

The column of amphiarthrodial joints between the vertebral bodies i.e. the intervertebral discs is very stable. Being of semi solid fibrocartilaginous structure and being bound by inelastic and nonstretchable ligaments these joints allow the adjacent vertebral bodies to undergo only tilting movements and to-and-fro displacement in various directions.

By contrast the true diarthrodial joints between the articular facets being lined with synovial membrane and enveloped by elastic ligaments have a relatively wide range of motion. Steindler states that the posterior ligaments are so elastic that if one separates the column of posterior arches from the column of vertebral bodies a shrinkage of 14 per cent in the length of the former occurs. This corresponds approximately to the difference in length of the posterior surface of the vertebral bodies in the positions of normal erect rest when the various posterior ligaments are on tension and in complete posterior extension when they are contracted. In Figure 4 the difference is seen to be about 12 per cent between these two positions. The ultimate degree of displacement and curvature in any movement is determined by the planes and dimensions of the articular facets and the angles at which they are placed to the bodies. For example in forward flexion of the cervical spine the inferior articulating facet of each process glides upward and anteriorly upon the superior facet of the vertebra below. In so doing it causes each vertebral body to be displaced forward

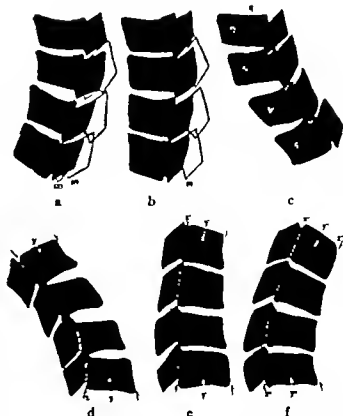


Fig. 4. Schematic tracings from roentgenograms of normal cervical spine. a, Maximum retroflexion. b, normal erect position. c, anteflexion chin flexed upon chest. a, b, articular process. b, body. a, b, and c illustrate relative positions of articular facets in various positions. Note upward and anterior gliding of each articular facet upon the one beneath it, in anteflexion, and the reverse in posterior flexion. d, e, and f. Same, illustrating the relative positions of the vertebral bodies in same phases as in a, b, c. In retroflexion d, each body projects posteriorly upon the one below and conversely in anteflexion e, the offset is anterior. The summation of these small upward and forward displacements produces the interval between d and f. This occurs by changes in the shape of the intervertebral disc, doubtless by realignment of the direction of its constituent fibers, rather than by true compression. The lines F, F' and F'' remain equal in all positions; there is, therefore, no actual elongation or shortening of the column of vertebrae. The perimeter of the sector does not change in the various positions and therefore since the bony contour remains constant, the changes in shape of the intervertebral disc are not due to expansion nor contraction as in the elastic posterior ligaments.

upon the one below (Fig. 4b). In this forward displacement of the vertebral bodies the nucleus pulposus acts as a pivot more or less comparable to a roller bearing. The shape of the intervertebral disc changes becoming widened posteriorly and narrowed anteriorly. The summation of these small upward and anterior displacements of the bodies permits a wide excursion of the head and upper cervical spine upon its fulcrum at the relatively less mobile

cervicothoracic junction. As seen in Figure 4 the mechanical advantage of flexing the head posteriorly is greater than in anterior flexion. This is because the intervertebral discs have greater depth anteriorly that is they have longer fibers and for that reason are capable of wider separation when the head is retroflexed. Another contributing factor is the tendency of the elastic posterior ligaments to contract.

At this point it seems desirable to correct the misnomer in common general use and in anatomy textbooks of the term "compression" of the disc on that aspect of the spinal column which becomes concave in any given movement. The tendency toward compression by the vertebral column is countered by the nucleus pulposus. The latter is quasi-liquid and is tightly surrounded by the flexible but inelastic matrix of fibrocartilage constituting the disc. This inelastic capsule consisting of the fibers of the annulus fibrosus and of the anterior and posterior longitudinal and the lateral ligaments, tends to maintain the over-all dimensions of the disc unaltered under normal conditions of stress and movement. In the normal erect position of the spine the alignment of the vertebral bodies is such that a smooth unbroken line is presented toward the spinal canal by their posterior surfaces. In complete forward flexion of the cervical spine each superior posterior edge of the vertebra projects into the spinal canal, and during complete extension the inferoposterior border of the vertebral body projects into the canal so that there is a definitely broken line in the bony contour of the spinal canal (Fig. 4b). It may be stated that there is no true compression or elastic stretching of the soft parts of the discs but merely a realignment of their constituent fibers. This phenomenon gains importance in the problem under consideration. That is, when an extreme force has been applied to the cervical spine in flexion having reached the point of maximum normal displacement and being neither contractible nor expansible either the bone or the ligamentous structures must give way under the force. Inasmuch as the elastic ligaments of the posterior arches are capable of stretching they are more apt to remain relatively intact and contract

back to their normal length and position after ward.

However if the force producing violent flexion of the neck is too great the disparity between the expansible properties of the two sets of ligaments will necessitate a rupture of the inelastic fibers maintaining the nucleus pulposus within its confines and it will either herniate through the weakened fibrocartilage or project the force applied to it through the weakened area thus directly injuring the spinal cord.

It is patent that there is a great disparity between these facts, both anatomic and pathologic, and the reasoning which has previously been employed to explain the phenomenon under consideration. It is apparent that the explanation of spinal cord transections without tangible evidences of disjunction of the vertebral column has been based on an improbable theory. It has been promulgated despite factual patent evidence to the contrary the significance of which has been underemphasized. Critical examination and evaluation of all of the phenomena observable in these cases will doubtless reveal much more importance of the intervertebral disc than has heretofore been recognized.

SUMMARY AND CONCLUSIONS

1. The report of a case of injury by diving into shallow water is presented. The cervical cord of the patient was almost completely severed anteriorly without any evidence of dislocation present of the spinal column.
2. At postmortem examination there was revealed a protruded intervertebral disc directly opposite the lesion present in the spinal cord.
3. The previously held theory that such lesions were due to a momentary extreme vertebral dislocation with immediate spontaneous reduction is held improbable on anatomic grounds.
4. Violent protrusion of the intervertebral disc, due to compression of the nucleus pulposus or herniation of the latter is proposed as the true mechanism producing the injuries to the spinal cord in this special type of traumatic paralysis.

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OBSERVATIONS ON DISPLACED FRACTURES OF THE HAND

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THE common occurrence of fractured metacarpals and phalanges inadequately treated with much resultant disability has interested us in methods which we report herein. Surgeons are aware of the anxiety and interest displayed when a patient with a major fracture enters the hospital. In contradistinction, a patient with fractures of small bones is ignored and left to the inexperienced to be treated. He is then discharged to an out patient department and lost sight of until malunion brings him back, often for operative correction.

This paper deals with baseball finger, displaced fractures of phalanges, displaced fractures of metacarpals, and fractures involving joints.

BASEBALL FINGER

Contrary to some opinion, we believe that satisfactory functional and cosmetic results can be obtained by carefully applied closed methods in cases seen within the first week. Simple hyperextension of the distal phalanx as obtained by means of a padded tongue depressor is unsatisfactory and will yield poor end results. Immobilization of the involved finger with malleable plaster or a well fitting aluminum splint, with flexion at the proximal interphalangeal joint and hyperextension at the distal interphalangeal joint (Fig. 1) has proved satisfactory in our hands. We emphasize the position, as we believe that adequate hyperextension can be obtained only by relaxing the flexor tendon. A word of warning regarding the use of plaster: it should be snugly applied and a dorsal section corresponding to the shape of the nail should be cut out so that the finger tip may be observed for circulation. Care in the original splinting, with observation for the first 12 to 24 hours may make the difference between union of an avulsed fragment to its bed and a permanently dropped finger. For cases seen after the first week, open operation is usually necessary. This procedure is recommended only for those in whom the distal phalanx is an encumbrance.

PHALANXES

In the treatment of fractured phalanges we have employed a method of fixed traction which

has several advantages over commonly used methods. Our procedure utilizes a traction splint incorporated in plaster as described in a previous paper. Briefly it consists of an aluminum alloy splint extending from the palm to just beyond the tip of the finger. The palmar portion has four flanges to facilitate incorporation in plaster. The shaft is the width of the finger and in its distal portion has two flanges forming a trough. In these flanges, parallel vertical notches 4 millimeters apart engage the needle used for transfixion. The technique of using the splint is as follows: Under local or intravenous anesthesia the fracture is reduced and the pulp of the distal phalanx or the normal phalangeal bone distal to the fracture site is transfixed. The proximal portion of the splint is then incorporated in plaster which extends from the metacarpophalangeal joints to the lower half of the forearm, the fingers are left free and the wrist immobilized in slight cock-up position. The shaft of the splint is then bent into optimal position for maintaining alignment, with care to keep in mind the functional position for the finger. Traction is then made on the finger through the transfixing needle, and the latter is inserted into the parallel notches which provide corrective tension and fixation. The finger rests on the splint; the latter is covered by a layer of gauze (Fig. 2). Immediate x-ray or fluoroscopic check is made. Minor alterations in traction may be made by further flexing the splint to increase, or extending it to decrease, the degree of pull. For additional security we employ a piece of thread or wire looped around each end of the needle and tied beneath the splint. This is a precautionary measure against disengagement of the needle and is useful in dealing with active ambulatory patients who are exposed to trauma. After 3 to 4 weeks, depending upon the obliquity and degree of displacement of the fracture, a test for bony union is made as follows: The traction is released by extending the splint, and the engaged needle is lifted out of the notches. The finger is thus freed for clinical examination, and following x-ray confirmation of satisfactory position the plaster with

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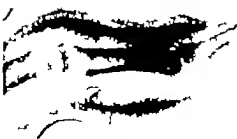


Fig. 1. Position for immobilization of "baseball finger" plaster

lint and transfixing needle are removed. Another week is devoted to controlled active physiotherapy.

Figures 3 and 4 illustrate Cases 6 and 7 respectively. Fractures of the phalanges involving joints are considered under separate heading due to the different problems involved.

METACARPALS

In the treatment of fractured metacarpals we have used a method recently reported as new but which we employed as far back as 1936. We learned the procedure from Colonel W. W. Lasher following closed reduction of the fracture by traction on the flexed finger. A Kirschner wire is passed through the heads of the affected and its adjacent metacarpal or metacarpals. In the case of fracture of the 5th metacarpal or the much rarer 2nd metacarpal it is necessary to incorporate the emergent wire under tension in a plaster gauntlet, leaving all the metacarpophalangeal joints free. The latter serves as a means of external fixation while the adjacent metacarpal serves as a fulcrum. We stress this point because the Kirschner wires employed are not sufficiently rigid to maintain traction unaided. In fractures of the 3rd and 4th metacarpals one may dispense with plaster except to protect the protruding wire end from trauma.



Fig. 2. Fixed traction splint showing incorporation in plaster cast.

This procedure may be utilized in compound as well as simple fractures. Its usefulness may be extended to cases of shaft fracture with marked displacement of the fragments. A second wire passed through the proximal fragment and adjacent metacarpals following reduction provides



Fig. 3. Before and after reduction. Case 6, comminuted fracture of shaft of proximal phalanx left 4th finger.



Fig. 4. Roentgenograms before and after reduction. Case 7, compound comminuted fracture of shaft proximal phalanx left 5th finger.

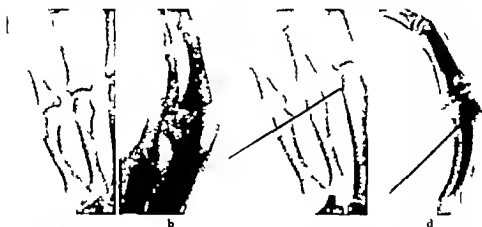


Fig. 5. Roentgenograms before and after reduction, Case 6, comminuted fracture distal end and head of metacarpal right 5th finger.

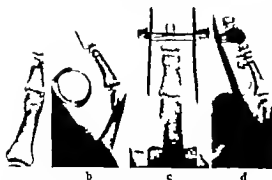


Fig. 6. Roentgenograms before and after reduction, Case 8, oblique fracture of head of proximal phalanx 5th distal location. 1) proximal interphalangeal joint and displacement of anterior portion of head anteriorly left 5th finger.

an adequate means of maintaining good alignment.

The method has the advantage of allowing immediate motion in all the joints of the affected and normal fingers. Other forms of traction through the phalanges result in prolonged disability due to the long period of immobilization. Using the latter methods one cannot help being impressed with the fact that joint complications in the finger used for traction are sometimes more disabling than the fractured metacarpal itself. Figure 5 illustrates Case 16.

FRACTURES INVOLVING JOINTS

Fractures and fracture-dislocations involving joints in which more than 50 per cent of one surface is involved frequently terminate in ankylo-

sis. This complication particularly in the proximal interphalangeal joint is so disabling that the patient may request amputation. Bone block may also complicate these fractures and frequently requires operative correction. We believe that traction in the position of function, followed by active motion in 3 weeks will circumvent these sequelae in many instances. Traction reduces the displaced fragments, realines the joint surfaces and at the same time maintains the joint spacing so that the tendency to heal across and ankylose is minimized. Figure 6 illustrates Case 22.

ALLIED CONDITIONS

The principles enumerated have been applied satisfactorily to allied conditions such as fractures of the 1st metacarpal, fractures of the metatarsals, lacerations of tendons involving joints, and human bite infections involving the metacarpo-

phalangeal joint. In using the traction splint for displaced fractures of the first metacarpal applied to the dorsal surface, we have had to rely on the wire loop to keep the needle from slipping out of the notches. Therefore we are not yet disposed to credit it with any advantages over the familiar banjo-wire method.

SUMMARY

1. 'Baseball finger' displaced fractures of phalanges and metacarpals, and fractures about joints have been discussed.

2. Fixed traction methods, which are simple and reliable have been considered. We have had no complications from their use and good functional and anatomical results have been obtained.

3. Traction in the treatment of fractures about joints, as well as other conditions involving joints is recommended.

TOTAL AND PARTIAL PATELLECTOMY

An Experimental Study

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TOTAL excision of the patella is not a new procedure. It was used as early as 1860 by Putz and by Fowler in 1871 for the treatment of habitual dislocation of the patella. In 1889 Page recorded a case of removal of the patella for "acute necrosis." Patellectomy was utilized in the treatment of fracture by Altham in 1890 followed by Scudder (1898) Le Boutillier (1903) and Willis (1907). Tait, who used this method for treating fractures in 1900 stated that many have an exaggerated idea of the importance of the patella, which is merely a sesamoid bone.

John B. Murphy performed patellectomy in 2 cases of tuberculosis in 1908. Basing his judgment upon the work of Jouchimathal and emphasizing the fact that certain animals using their quadriceps extensively like the kangaroo, have no patella, Murphy claimed that the patella is not essential for perfect mobility and function of the knee joint. Herneck, in 1909, made an analytical study of over 100 cases of fracture of the patella treated by the operative method. He found that complete removal of the patella had been performed for chronic osteomyelitis, tuberculosis, fracture, and primary malignant disease and that extirpation of the patella is always a sacrifice.

From 1909 until 1936 interest in total removal of the patella abated or the procedure fell into disrepute. In 1936 Blodgett and Fairchild proposed what they considered a new conception of the treatment of the acute fracture of the patella, namely the method of subtotal resection of the patella or when indicated, total excision. They claimed that this procedure is "productive of excellent clinical results and is justified in the light of functional anatomy of the knee joint. Impetus was added to the subject in 1937 by Brooke (9, 10) whose work is now extensively quoted. He advanced experimental and other evidence to show that in the absence of the patella "the efficiency of the knee-joint is, if anything, increased both as regards the rapidity of movement and power."

Since 1937 many publications have appeared appertaining to the removal of the patella for

fracture (13, 15, 19, 22, 25, 29, 30, 33) and for arthritis (1, 6). Warnings against the adoption of such a procedure routinely, however are beginning to appear in the literature (11, 12, 16, 17, 31). Bruce and Walmisley (1942) performed experimental excision of the patella in rabbits, and reported degenerative changes in the articular cartilage, especially in the patellofemoral surface. In the same year Gardil, using dogs as the experimental animal, noted that patellectomy resulted in a reduction of active motion, an increase in passive motion, degenerative changes of the articular surface of the internal condyle as well as the intercondylar sulcus, and atrophic changes of the extensor mechanism.

The present work was begun in January, 1943 before the appearance of Bruce and Walmisley's paper. The purpose was to ascertain the effects, if any, of total and partial excision of the patella on the structure of the knee joint both in young and adult rabbits. Since it was believed that function could not be satisfactorily tested clinically in the rabbit, specimens of the quadriceps muscle were taken from animals of each group in order to study histologically any changes which might have been caused by malfunction.

METHOD

Twenty-eight normal healthy rabbits were used in the experiments. Group I consisted of 14 adult animals, whose weights ranged from 2.16 to 4.09 kilograms at the beginning of the experiments. Group II contained an equal number of young animals, the weights of which varied from 778 to 1,355 grams. Each of these groups was subdivided into two equal groups. In the one, the entire right patella was removed, the left serving as the control. In the other, approximately one-half of the patella on the right was excised, the left again being the control.

The animals were fed a substantial balanced diet throughout the course of the project. All animals gained weight. They were permitted to run at large for exercise in a room at least 4 days weekly. With the exception of a few rabbits which died within 4 months, all the animals were killed at the termination of the experiments varying from 10 to 12 months.

From the Research Department, National Jewish Hospital and the Department of Pathology, University of Colorado School of Medicine.



Fig. 1. Total patellectomy in adult rabbits. Roentgenograms of knee joints showing small masses in patellar tendon (animals B1R and B3R), irregularity of the femoral condyles (animals B1R, B3R and B7R) and rarefaction of the femoral condyles (animal B6R). Control extremities are marked "L"; extremities operated upon "R".

Operative procedure. The anesthesia used was a 1½ per cent solution of sodium pentothal ad-

ministered through the marginal ear vein. The right knee region of each animal was surgically

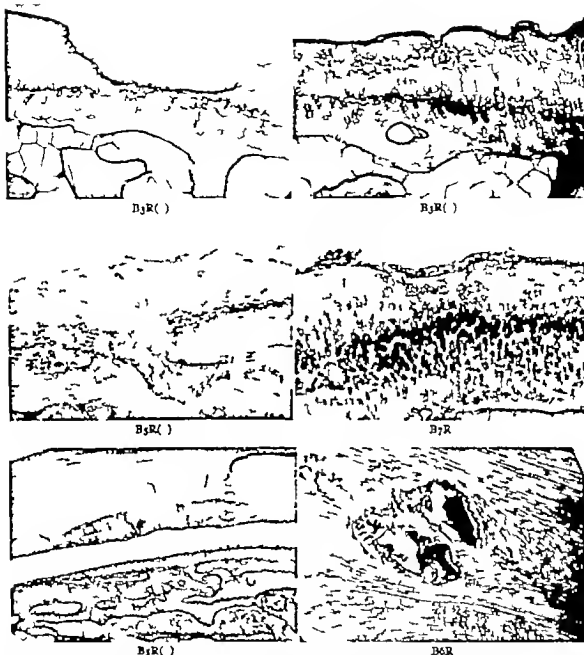


Fig. 1. Total patellectomy in adult rabbits. Animal B3R () illustrates an area of deep excavation of the femoral condyle ($\times 40$). B4R () shows irregularity of the femoral condyle. Weibelbaum's lacunae and vascularization of the cartilage ($\times 40$). Note fibrillation of articular cartilage in B5R () ($\times 40$). Fibrillation, early ulcerative

lesion and clustering of the cartilage cells are seen in B7R ($\times 50$). B4R () shows fraying of the patellofemoral articular surfaces and two bony masses at previous site of patella ($\times 40$). Metaplastic bone formation is seen in the distal third of the patellar tendon of animal B6R ($\times 70$).

prepared. The patella was exposed through a small vertical incision, and was enucleated by

very careful subaponeurotic dissection. The quadriceps aponeurosis was then meticulously sutured

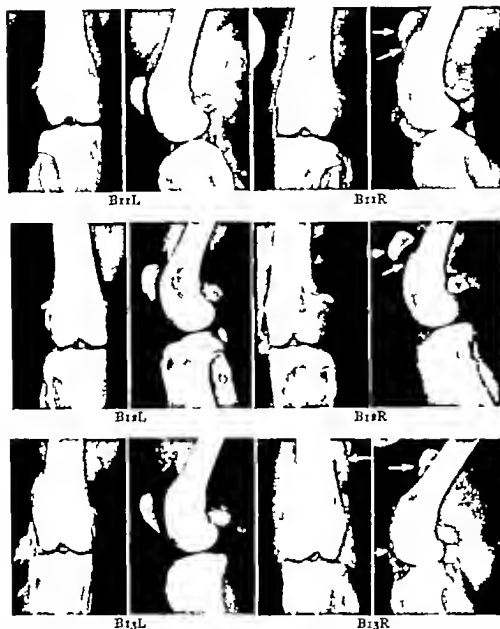


Fig. 3. Partial patellectomy in adult rabbits. Roentgenograms of knee joints illustrating high position of the patella, rounding of the apex and demarcation between the old and regenerated portions of the patella. Varying degrees of bony proliferation of the femoral condyle opposite the patella is seen in all animals. Br3R shows irregularity of the femoral condyle. Control extremities are marked "L," extremities operated upon, "R."

together with the patellar tendon with Deknatel No. 1. The skin was closed with similar sutures.

In the groups in which one half of the patella was excised the apex was carefully freed from the attachment of the patellar tendon. A rongeur was used to remove as nearly as possible 50 per cent of the bone. The patellar tendon was then meticulously reanchored to the patella and mesial and lateral expansions of the quadriceps with Deknatel No. 1. No subcutaneous sutures were used. The skin was closed by means of 2 or 3 sutures of similar material. The wounds healed *per primam*

with the exception of a few minor superficial infections.

Technical procedures. Several animals were chosen at random from each group for x-ray examination of the joints 6 months after the beginning of the experiments. At the termination the amputated extremities of all the animals were x-rayed in the anteroposterior and lateral positions. The limbs were immediately skinned and placed in 10 per cent formalin. Gross pathological studies were not made because they would distort the anatomical relationships. Following fixation

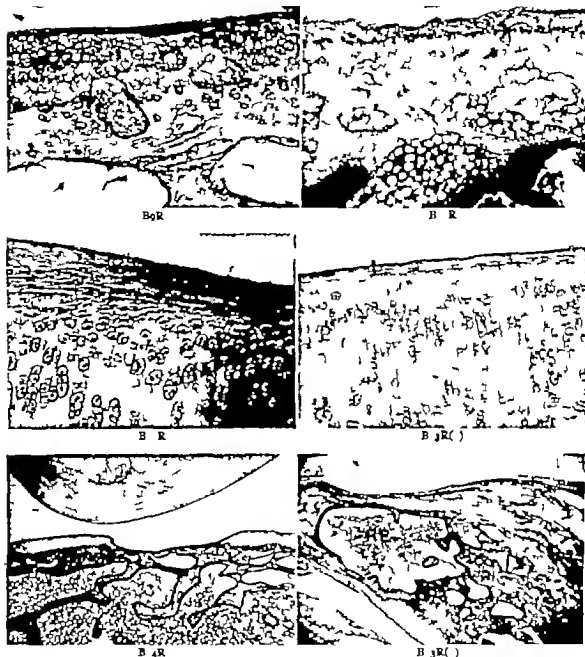


Fig. 4. Partial patellectomy in adult rabbits. Animal BqR shows vascularization and cellular proliferation of the articular cartilage (\times). Note irregularity and vascularization of femoral condyle in B R ($\times 37$) B R ($\times 30$)

and B 3R ($\times 95$) evinces fibrous stratum of femoral condyle. B 4R shows an area of deep excavation of femoral condyle ($\times 8$). B 3R (\times) shows regenerated area of patella (RE) the apex of which is rounded (\times)

the material was decalcified in 5 per cent nitric acid. The joints were then bisected sagittally one-half was prepared by means of the paraffin method, the other by celloidin. The celloidin

sections were stained by the Bock technique (28)

An adequate specimen from the quadriceps muscle of each animal was taken for study. This material was prepared by the paraffin method

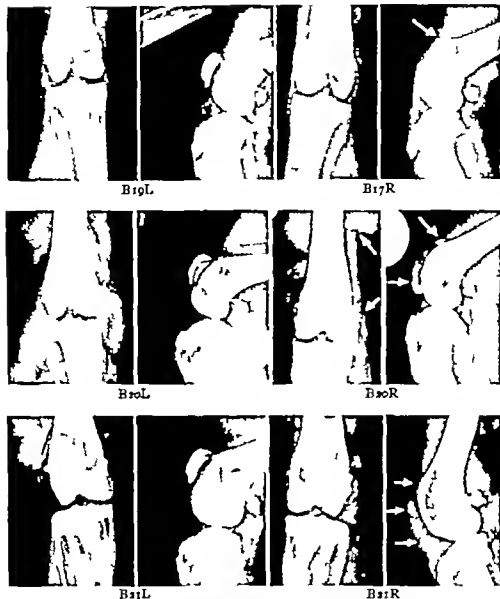


Fig 5 Total patellectomy in young rabbits. Roentgenograms of knee joints showing masses resembling bone in the quadriceps tendon (animals B17R and B20R) and in the patellar tendon (animals B20R and B21R). The apparently reformed patella on the lateral view in animal B20R is resolved into superimposition of several shadows on the anteroposterior view. Control extremities are marked "L," extremities operated upon, "R."

RESULTS

A detailed study of each roentgenogram and histologic section was made. The changes which were noted in each group differed from one another only in degree or extent. The data, therefore, will be presented as a whole for each group and the various changes will be illustrated by particular lesions in the individual animals. The findings will be grouped under headings which represent the experimental procedure.

Group 1 Total patellectomy in adult rabbits
Clinically one could not distinguish between the extremities operated upon and the control. Weakness or limp could not be detected. No tendency

to protect the leg operated upon was observed after complete healing of the wound.

X ray examination at the termination of the experiments did not reveal any evidence of regeneration of the patella in 5 of the 7 animals. In 2 animals (B1-B5) small dense masses were noted in the patellar tendon at the previous site of the apex. Two joints (B6-B7) showed definite rarefaction and irregularity of the femoral condyles. The irregularity was mainly at the previous site of the patella. The remainder of the joints showed no articular abnormalities (see Fig 1).

Histologically all the joints evinced definite degenerative changes of the articular surfaces.

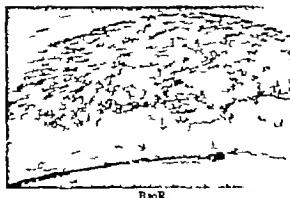


Fig. 6. Total patellectomy in young rabbits. Photomicrographs illustrating types of osseous masses found in

patellar tendon (B30R, $\times 37$) B R, $\times 74$) None of the masses contained marrow spaces.

The findings consisted of vascularization, Weibselbaum lacunae and nuclear changes. The majority of the sections revealed irregularity of the articular margins. Many areas of excavation or complete denudation of cartilage were found. A constant observation was a fibrous stratum overlying the hyaline cartilage, which was not observed in any of the controls. The articular changes were situated mainly but not exclusively in the patellofemoral region of the condyles (see Fig. 3).

The tibial condyles were free from degenerative changes with the exception of infraction of the articular cartilage which was noted in several animals.

Group II Partial patellectomy in adult rabbits. These animals did not exhibit any aberrations of function clinically. No attempt to favor the operated limb was observed.

On x ray examination it was noted that the patella was situated somewhat more proximally than the control extremities. The apex of the patella in each instance was rounded instead of pointed as it is normally and was less dense than the undisturbed portion of the patella. In several animals the demarcation between the old and the regenerated portions of the patella could be seen. With the exception of one animal (B 3) no articular changes were found. However almost all the animals showed what appeared to be bony proliferation at the proximal end of the femoral condyles opposite the location of the patella (see Fig. 3).

Microscopically the articular changes were much less evident than in the group of complete patellectomy. The only consistent finding was a fibrous stratum covering the femoral condyles. One animal (B9) showed early vascularization with cellular proliferation of the femoral articular cartilage. Areas of excavation in the proximal portion

of the condyle were noted in 3 animals of this group (B12 B13 B14). These areas, however, were not as extensive as those found in Group I. The tibial condyles were essentially negative in all sections (see Fig. 4).

Study of the patellae did not reveal any striking distinctions between the old and the regenerated portions. The latter however consisted of less dense adult bone. No callus tissue or young bone was found in any of the sections. The lower pole was not covered with hyaline cartilage; it was surrounded by dense fibrous tissue (see Fig. 4).

Group III Total patellectomy in young rabbits. It was not possible clinically to ascertain any weakness, limp or loss of function of the extremities operated upon with the exception of one animal which used the right leg very poorly. This animal was discarded from the series. The propulsive power of the patellectomized leg was apparently equal to that of the extremity not operated upon.

Small shadows with bone like appearance in the patellar ligament were noted on the roentgenogram of each animal in this group. They ranged in number from 3 to 5 and varied somewhat in size. No instance was found, however, of an attempt to reform a mass resembling a patella. It is noteworthy that the animal which obviously had a very poor result immediately after operation and used the leg very little showed but a single small shadow in the patellar ligament. No articular changes or rarefaction of the condyles were observed in this group (see Fig. 5).

The only positive histologic finding was a thin fibrous stratum covering the femoral articular surfaces. This layer was somewhat narrower than that noted in the corresponding adult series. The cartilage was otherwise essentially negative. There were no abnormalities of the tibial articulation.

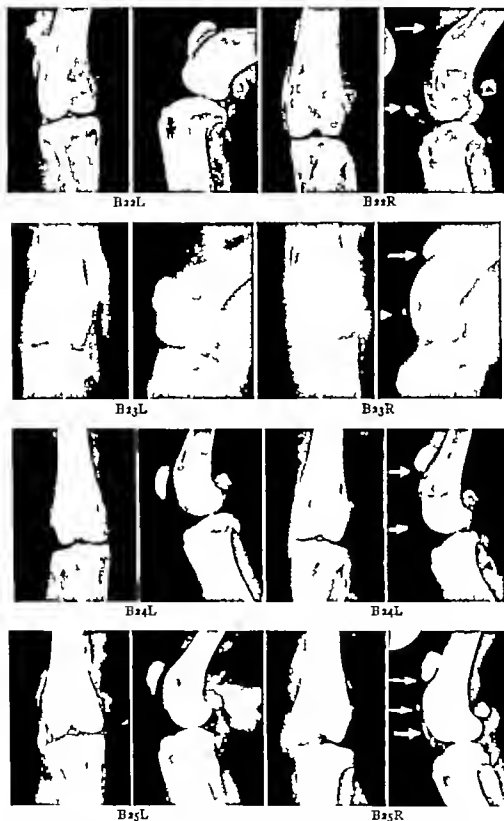


Fig 7. Partial patellectomy in young rabbits. Roentgenograms of knee joints illustrating high position of the patella and rounding of the apex. Note shadows resembling bone in the patellar tendon. Control extremities marked L, extremities operated upon, "R."

The masses of bone noted on the roentgenograms were found on histologic section. They were located in the quadriceps tendon at the site of patellectomy. They were buried in fibrous tis-

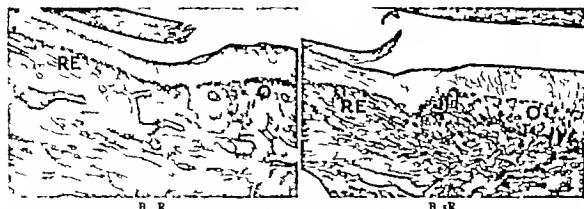


Fig. 8. Partial patellectomy in young rabbits. Photomicrographs showing offset between old, *O* and regenerated, *RE*, portions of patella. Not differences in articular covering of these regions (*B R*, $\times 37$; *B 3R*, $\times 3$)

sue and did not resemble normal bone. None of the osseous masses contained marrow spaces (see Fig. 6).

Group II. Partial patellectomy in young rabbits. The clinical results in this group were comparable to those of the other series experiments. As in the previous experiments no differences between the operated-upon and control extremities were apparent.

On roentgenographic examination no definite articular changes of either the femoral or tibial condyles were found. In each instance the patella was situated somewhat more proximally than in the control. A similar finding was noted in the adult series. The distal pole of each patella was rounded instead of pointed as is found normally. The apex was also less dense than the undisturbed portion. Six of the 7 knee joints showed small shadows with bone like appearance in the patellar tendon, resembling those observed in the complete patellectomy series (see Fig. 7).

Histologic study did not reveal any changes of the femoral or tibial articular surfaces. Regeneration of the patella was noted as observed on the roentgenograms. A step-like offset marked the previously undisturbed from the regenerated portions of the patella. The latter was not covered with hyaline cartilage; the articular surface consisted of dense fibrous tissue. The structure of the regenerated areas was composed of mature lamellated bone. No callus tissue or young bone was found. The hyaline articular cartilage of the patella did not reveal any pathological changes (see Fig. 8).

The small shadows which were observed in the patellar tendon on the roentgenograms were osseous masses. They were constructed of mature bone and were buried within the patellar tendon (see Fig. 9). They were found only in areas which were the sites of the surgical intervention. In one animal an osseous nodule was noted where a Deknatel suture was still present (see Fig. 10).



Fig. 9. Photomicrograph of osseous mass found in patellar tendon ($\times 37$)

Fig. 10. Bone formation, *BF* in patellar tendon at site of persisting Deknatel suture, *D* ($\times 37$).



Fig. 11 Photomicrograph of representative control section (X35) Q Quadriceps tendon P patella FC, femoral condyle PT patellar tendon CL, cruciate ligament T tibia.



Fig. 12 High-power magnification of patellofemoral surface marked on control section (X85) Note smoothness of articular surfaces and regularity of cellular arrangement. P Patellar cartilage F femoral cartilage.

Quadriceps muscle Histologic study of the quadriceps muscle revealed no atrophic changes.

ANALYSIS OF STUDY

The data obtained from the experiments on complete patellectomy in the rabbit indicate that this procedure results in definite pathologic changes of the articular cartilage. These changes are interpreted as degenerative arthritic (osteoarthritis) in nature. The degenerative findings are much more marked in the adult group than in the young in which the only change noted was a fibrous outer layer of the hyaline cartilage.

The localization of the pathological process mainly along the patellofemoral surface of the femoral condyles suggests that the osteoarthritic changes are caused by friction of the patellar tendon against this region of the condyles. Once these degenerative changes occur they are probably progressive.

It would indeed be surprising if complete patellectomy did not give rise to degeneration of the articular cartilage. Bennett and co-workers (4, 5) have shown that even 'simple functional derangements such as patellar displacements lead

to marked and typical changes of osteoarthritis. Patellectomy is more than just a simple functional derangement of the joint since it disturbs the normal mechanics of the quadriceps mechanism.

Although removal of the patella elicits degenerative changes in the young animal, the findings are less marked than in the older subject. Articular cartilage in young specimens is more resilient and therefore more resistant to friction produced by the patellar tendon. It is logical to assume, however, that if the younger animals were permitted to survive for longer periods, more advanced osteoarthritic changes would make their appearance. The end result would be the same.

The small osseous masses observed in the patellar tendon of 3 adult animals and in all animals of the young group in which total patellectomy was performed could not be interpreted as an attempt at replacement of the patella as mentioned by Bruce and Walsley. They appeared to be much too small to serve the previous function of the patella. In no instance did the structure of these bony nodules approach normal bone in the adult series. Furthermore bony masses were also found

in the patellar tendon of several animals in the partial patellectomy series. It would be difficult to explain their appearance in this group solely on the basis of an attempt at patellar replacement. Areas of ossification in all groups most likely represent metaplastic bone as the result of stress and strain on the surgically injured patellar tendon.

Partial patellectomy in the adult animals resulted in a fibrous stratum of the femoral condyles. This finding may be explained upon the basis of a high-riding patella, interfering with the normal function of the quadriceps mechanism. Since the extremities were not immobilized after operation, the patellar tendon did not become reattached at the point of suture. On the other hand partial patellectomy in the young group did not evoke degenerative changes. This may be accounted for by the fact that in young animals the articular cartilage is more resilient and better able to absorb the trauma of the high position of the patella than it is in older animals. The experiments on partial patellectomy indicate that there is an attempt to restore the patella to its original size both in the adult and immature rabbit.

In interpreting the experimental data in relation to the human subject one must bear in mind the differences in the mechanics of the rabbit as compared to the human knee joint. These observations, however suggest that routine total patellectomy for fracture of the patella in the human may be folly. It is agreed that in severely comminuted fractures of the patella it is purposeless to attempt to reconstruct the patella. Traumatic arthritis is the inevitable sequela. The degree of traumatic arthritis in such instances would be much greater than the degenerative arthritis following patellectomy. On the other hand total removal of the patella in those cases of fracture in which a reasonable degree of anatomical position can be attained would appear to be definitely injurious to the joint. The protective value of the patella is obvious and is not considered here.

Although complete patellectomy in an advanced osteoarthritic joint may give relief of pain and possibly improve joint function purely by removing a mechanical obstacle, such a procedure may in the final analysis hasten the degenerative process which one has attempted to stay. This can be definitely ascertained in the human only by an accurate study over a long period of time. Roentgenographic interpretation alone of patellectomized joints will not suffice. Gross and histologic examinations must also be made. The author's experimental data reveal that histologic findings are much more marked than the roentgenographic findings in all instances.

SUMMARY

1. Total patellectomy in the rabbit resulted in degenerative arthritis (osteoarthritis) of the tibio-femoral articulation. The pathologic changes were more marked in the adult than in the immature animal.

2. Partial patellectomy in the adult rabbit evoked early degenerative changes of the femoral condyles as manifested by a fibrous outer stratum.

3. Partial patellectomy in the young animal did not produce articular changes (at least during the 12 month period of the experiments).

4. No clinical aberrations of function were noted in either the total or partial patellectomy series. Histologic study of the quadriceps muscle did not reveal any atrophic changes.

CONCLUSION

At the present state of our knowledge it would appear that total patellectomy in the human should not be performed except in those instances in which such a procedure cannot be avoided.

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A NEW STITCH FOR USES IN PARTIAL GASTRECTOMY

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THE stitch described here is new only in the sense that it is new in the field of surgery. In reality it is an adaptation to surgical uses of the stitch made by the ordinary domestic sewing machine. The sewing machine it will be remembered uses two threads. One is called the top thread and is carried by the needle. The other is called the bobbin thread and is carried in a shuttle. In making the stitch the shuttle is made to pass through a loop in the upper thread after the needle has passed down through the cloth or material. The two threads are thus locked, making a very strong seam.

The adaptation of this to uses in the performance of gastrectomy is made in the following way. The effect of two threads is accomplished by using both ends of the gastroenterostomy suture. The suture is passed through the stomach wall just beneath the distal end of the Payr clamp a short distance from the upper border of the stomach, and tied. The end of the suture commonly called the *short end* is left long (about one-third the length of the ordinary Duxor suture). It now acts as a bobbin thread. It is held taut against the stomach wall just below the border of the Payr clamp and on the side that is in the vision of the operator (Fig. 1). The needle is introduced from the opposite side and brought through and over the top of the bobbin thread and is passed back below the bobbin thread and through the same needle hole. The bobbin thread is thus placed in a loop of the upper thread. The two threads are locked as in the sewing machine stitch. The bobbin thread can be shifted up and down at the proper time by an assistant, so that a loop is formed over the bobbin thread without loss of time. This maneuver is continued all the way across the cut edge of the stomach with the Payr clamp serving as a straight edge, until the two ends are tied around the opposite border of the stomach.

The Payr clamp is then removed and the crushed portion of the stomach wall is excised (Fig. 2). It is safe to cut the tissue away very close to the suture line. This is facilitated by the fact that the suture line is straight. If caution is observed to keep both *strings taut* there will be no leaking through this suture line and no bleeding. One

can then use whatever inversion stitch he prefers. Personally I have found one running stitch sufficient to make a strong closure of the stomach wall (Fig. 3).

The same procedure is followed in closing the duodenum. The space between each needle hole should be much less in closing the duodenum than in closing the stomach because the wall is much thinner and more delicate.

This same procedure can be followed in closing any portion of the severed stomach. For example in performing the Hofmeister procedure the closure can be interrupted at any point and the two ends tied. A small Payr clamp is then applied to the unsutured portion of the stomach in any direction one may choose to apply it. An angle of 45 degrees to the large Payr clamp will in most instances, give a horizontal line of suture with the patient in the upright position. The size of the stoma will be adequate also. The large Payr clamp is then removed and the crushed portion of the stomach together with the uncrushed portion below the small Payr clamp is excised. The anastomosis to jejunum is facilitated by the fact that such a small amount of stomach wall is used in accomplishing a safe, firm closure. Inverted stomach is not protruding inward to interfere with the lumen and later to block the opening.

I have used this stitch with a high degree of satisfaction. Dr. Barney Brooks, professor of surgery Vanderbilt University has used it also.

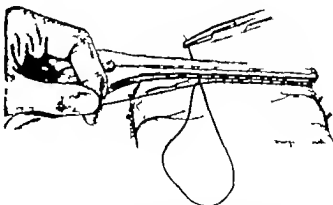


Fig. 1 The application of the suture. It will be noted that the needle is passed back through the stomach wall through the same needle hole after a loop is formed over the bobbin thread. The suture line is farther away from the clamp in the illustration than it is in actual use in order to accentuate the suture.



Fig. 2. The crushed portion of the stomach being excised. Note that the stomach wall on each side of the suture line presents a rolled appearance. This facilitates the placing of the inversion suture.



Fig. 3. The ordinary running suture which can be pulled with precision and speed. In addition, this stitch makes a very firm closure. Hemostasis is no longer a matter of concern.

with satisfaction, not only in gastrectomy but in closing the end of colon or small intestine in instances where a lateral anastomosis is to be performed. He has encouraged me to make this publication of it.

The advantages of the suture are as follows:

1. It accomplishes complete hemostasis.
2. It prevents any leakage.
3. It makes possible removal of the crushed portion of stomach and duodenal walls. Thus, in turn, facilitates the application of the inversion suture.

4. It prevents crushed stomach or duodenal wall from becoming involved in the inversion suture in any way.

5. A small amount of tissue is used in effecting a strong closure. A short duodenal stump can be safely closed without difficulty.

6. It avoids the presence of crushed stomach wall within the cavity of the stomach after the operation is completed.

7. It makes for precision in suturing which is always an aid to prompt healing.

ADENOCARCINOMA WITH CLEAR CELLS (HYPERNEPHROID) OF THE OVARY

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THERE is probably no organ within the body in which so many distinct tumor entities are recognized as in the ovary.

Schiller recently reported a new type of tumor adding one more to the many already known a tumor supposedly mesonephric in origin which he termed mesonephroma. The possibility of a mesonephric origin for certain ovarian tumors was considered because embryologically the gonads and the wolffian body develop in very close proximity. This is particularly true in instances in which the genital grooves are located more peripherally and the gonads are closer to the mesonephros. Inclusion of mesonephric elements in the ovary theoretically at least could occur in the latter instances. The characteristic features of supposedly mesonephric tumors are glomerulus-like structures and a complex system of cystic cavities lined by a layer of cells similar to those lining the Bowman's capsule, in which however the capillary tuft has failed to develop. The glomerular tufts in these tumors may also be distorted by the proliferation of accessory capillary loops or by abnormality in their size. Schiller also stated that, since the mesonephros gives rise to renal tubules it would be logical to assume that analogous tumor formations are represented in the mesonephroma. However tubules are very rarely encountered in these tumors. This is explained by the absence of the physiological stimulus which is present in organized embryonic tissue. Since the mesonephric vesicles normally empty into the wolffian duct, while misplaced mesonephric structures and tumors arising from these tissues do not the stimulus normally present for the formation of duct structures in misplaced mesonephric tissue is absent. Hence it is concluded that the growth of tubular structures is generally in abeyance.

There is a well recognized though rarely encountered yellow tumor of the ovary which produces clinical signs of masculinization. This tumor is believed by many investigators to arise

from misplaced suprarenal cortical cells within the ovaries and is termed hypernephroma though some disclaim such an origin and think it more likely that these tumors arise from luteinized granulosa cells and therefore speak of lutein cell tumors. The most significant argument against the assumption that the so called hypernephroma of the ovary arises from misplaced suprarenal cortical structures is based upon the fact that whereas these ovarian tumors are linked with masculinization similar tumors arising in the kidney do not produce alteration of the secondary sex characteristics. For this and other reasons many of the yellow tumors arising within the kidneys are not considered to originate from misplaced suprarenal cortical structures but to arise from the kidney tubules. Therefore these tumors in the kidney are not called hypernephromas but hypernephroid tumors (carcinoma) thereby implying that, though they resemble suprarenal tumors, they do not arise from suprarenal cells.

In the following attention is directed to an ovarian tumor which is bright yellow malignant and composed of epithelial cells microscopically different from either lutein cell tumors or true hypernephromas and which produces no change in the secondary sex characteristics. This tumor is thought to arise from persistent tubular structures of intra-ovarian mesonephric structures and is apparently similar to the hypernephroid carcinoma of the kidney or to use a more current nomenclature adenocarcinoma with clear cells of the kidney. Two tumors of this type have come to our observation. Because of the rarity of these tumors and because it is hoped that the report of these tumors may serve to clarify some of the controversial questions concerning so called hypernephromas and masculinizing yellow tumors of the ovaries it was believed that a report of these tumors might be of interest.

CASE 1: Only the most relevant findings are noted. A 46 year old female complained of an abdominal mass of 5 months duration, frequency of urination and incontinence. Five and one half years previously her uterus had been removed for "fibroids." She had lost about 50 pounds during the past 3 years. Physical examination revealed a poorly nourished female, not acutely ill. Temperature was 98 degrees F., pulse 110, per minute and arterial blood pressure 138/80. Hair distribution was normal. There was no evidence of change in secondary sex characteris-

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Fig. 1. Clear cell adenocarcinoma (hypernephroid carcinoma) of the ovary. Note the attempts at glandular formation and the clear lining cells. Iron-haematoxylin eosin preparation, X60.

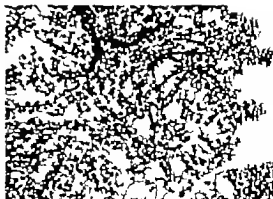


Fig. 2. Clear cell adenocarcinoma (hypernephroid carcinoma) of the ovary. Note the invasion by masses of tumor cells which show clear cytoplasm. Iron haematoxylin-eosin preparation, X.

lax. A large, firm, slightly movable, non tender mass extended from the symphysis almost to the level of the umbilicus. At laparotomy the left ovary as found to be firm, enlarged, and adherent to the bowel and urinary bladder. The right ovary as was enlarged, measuring about 5 centimeters in greatest dimension. The post-operative course was stormy. The elevation of temperature to 39 degrees, and death from peritonitis occurred 3 days after operation.

On examination the left ovary was found to consist of seminiferous mass weighing 800 grams and measuring 5 centimeters in greatest diameter. Projecting from the external surface were nodules which are firm and covered by pinkish-gray capsule, continuous with the external surface of the remainder of the mass. Much fat tissue and pieces of fibrous tissue are attached to the capsule. One area devoid of capsule the external surface as somewhat fibrillar and gray. A small cyst was recognized at one pole of the mass. On section it was



Fig. 3. Clear cell adenocarcinoma (hypernephroid carcinoma) of the ovary. Note the circumscribed accumulation of tumor cells completely filling cystic space. Iron-haematoxylin-eosin preparation, X 20.

found that most of the mass consisted of soft, friable, greenish-yellow tumor which here and there presented few translucent regions and areas of hemorrhage and necrosis. When a number of sections were cut from the tumor few arising sized cystic structures were encountered which are lined by smooth and glistening membranes and which apparently were not related to the tumor. The right ovary consisted of decompressed cystic structure, measuring centimeters in length, the inner lining of which was pinkish-gray, smooth and glistening.

The more important findings at autopsy are as follows. The distribution of hair conformed to the normal female habitus. The trunk and extremities were likewise of normal female configuration. When the abdominal cavity was opened 800 cubic centimeters of cloudy blood tinged fluid was noted. The peritoneal surfaces were dull or hemorrhagic and were covered with fibrin, and in the pelvic peritoneum few firm, obvious tumor nodules not exceeding 3 to 4 millimeters in diameter were present. These were yellowish and contained few foci of hemorrhage. The peritoneal and retroperitoneal lymph nodes are enlarged, firm, and replaced by grayish-yellow tumor tissue.

Histologic examination. Ovary.—Many sections of the ovary showed large areas of necrotic debris in which masses of epithelial cells were noted. In many fields these cells showed no particular arrangement. In some places they diffusely infiltrated the surrounding tissue and occasionally are arranged in groups well surrounded by moderate amount of newly formed connective tissue. In other sections the cells showed either tendency toward formation of glandular structures or actual glandular structures. Most of the cells showed clear cytoplasm with an eccentrically situated, vesicular nucleus. Occasionally the cytoplasm was stained slightly pink. Where the glandular structures were more pronounced, the cytoplasm was reddish. However sudden transition between cells showing clear and reddish cytoplasm was often encountered. Here and there the cells are arranged in the form of small papillae extending into the glandular lumen. The cells often varied in size, but usually were polyhedral in shape. The nuclei are round and showed an occasional mitotic figure. The chromatin of the nuclei was diffusely distributed, very delicate, and sometimes punctate. Accumulations of the cells were found in small veins. There are many foci of recent and old hemorrhages and necrosis.

Sections from the metastatic nodes showed cells similar to those here described. Here and there the cells were arranged in palisades. In sections of the lymph nodes the anaplasia of the tumor cells was much more pronounced than in the ovary. Sudan III stain for fat revealed numerous small fat droplets in tumor cells. The Best carmalum stain for glycogen in tissue removed at postmortem and fixed in absolute alcohol revealed red granules throughout the cytoplasm in a number of cells.

In summary, a yellow malignant tumor with foci of hemorrhage and necrosis was found in a 46 year old female who had shown no sign of change of secondary sex characteristics and who died of peritonitis following operation. The outstanding histologic features were the presence of malignant epithelial cells with clear cytoplasm similar to those seen in hypernephroid carcinomas of the kidney.

CASE 2. A 60 year old white female developed attacks of severe pain 15 hours before admission to the hospital. The past history was completely irrelevant. The menopause had occurred 5 years previously. There was no metrorrhagia. Physical examination revealed a mass in the left lower abdomen about the size of a large grapefruit, firm and movable. Bimanual examination disclosed that the mass was movable with the cervix. Temperature, respirations, and pulse were normal. At operation a large tumor was found which replaced the left ovary and was adherent to the rectosigmoid. The right ovary was cystic. A supracervical hysterectomy and bilateral salpingo-oophorectomy was performed. The patient made an uneventful recovery and left the hospital 14 days after the operation.

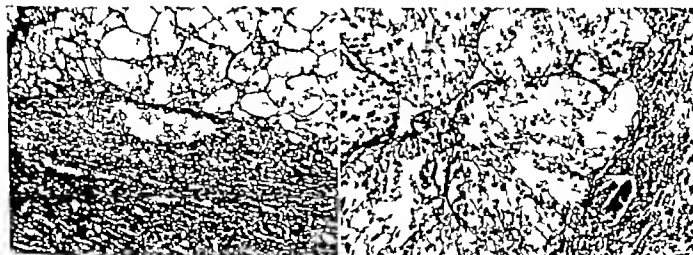
On gross examination it was noted that the specimen consisted of a uterus amputated above the cervix with attached fallopian tubes and ovaries. The uterus measured 4 centimeters across the fundus and 4 centimeters in length. Projecting subserosally in its posterior wall was a myofibroma measuring 6 by 9 centimeters. The endometrium was smooth and velvety. The myometrium contained several myofibromas measuring up to 1 centimeters

We are indebted to Drs. Siegfried and Herman Strauss for the clinical data.



Fig. 4. Clear cell adenocarcinoma (hypernephroid carcinoma) of the ovary. Higher magnification of a field shown in Figure 1. Iron hematoxylin-eosin preparation $\times 140$. (Note: The two tumors shown in Figures 1 to 4 did not produce masculinization.)

in diameter. The right fallopian tube was patent. Numerous translucent cysts, measuring up to 0.5 centimeter in diameter were present subserosally. There were dense fibrous adhesions between the uterus and both ovaries. The right ovary measured 2 by 3.5 centimeters and contained a cyst measuring 1.8 centimeters with a smooth



Figs. 5 and 6. Clear cell adenocarcinoma (hypernephroid carcinoma) of the kidney. Iron-hematoxylin-eosin preparation. Figure 5 $\times 105$. Figure 6, $\times 125$.

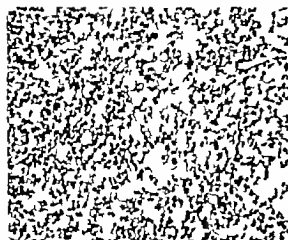


Fig. 7. Lutein cell blastoma (luteinized granulosa cell tumor) of the ovary. Iron-haematoxylin osm. preparation X 40. (Not this as masculinizing ovarian tumor.)

living. The left ovary as replaced by tumor measuring 7 by 7 centimeters, the surface of which as gray and fairly smooth. The elongated, patent left fallopian tube covered over its surface. The tumor consisted of cystic structure with smooth thin, grayish brown, 1 cm. area, extending into the lumen of the cyst there as large, solid, smooth tumor measuring 7 by 8.5 centimeters in greatest dimensions. On section the tumor as found to be partly firm and partly soft, coarsely granular and bright yellow, with obvious areas of hemorrhage and necrosis.

Histologic examination disclosed the following changes. Most commonly encountered are epithelial cells having clear or lightly stained pink cytoplasm and either darkly or lightly stained nuclei. The cells are square or polygonal. Often these cells, with hardly any recognizable stroma between them, entirely filled cystic spaces. There as an occasional capillary between the cells from which some of them seemed to arise. In other fields attempts at the formation of glandular structures or true glandular structures are encountered. The lining cells of these tubules are identical with those lining the cysts. Here and there the tumor cells are more compactly arranged in more or less circumscribed groups, thick bulged into cystic spaces. Capillaries are present between small rows of tumor cells. These structures somewhat resembled glomeruli, but nowhere could true glomeruli be demonstrated. Though it is obvious that the tumor cells had invaded ovarian structures to great extent, mitotic figures are relatively infrequent, and anaplasia as not marked. In other fields many papilliferous projections and glandular structures are encountered, lined by tumor cells with clear or pink stained cytoplasm. The nuclei of these latter tumor cells, however, are identical with those of the clear cells. The large cyst described grossly as not lined with tumor cells. In only one area had the tumor invaded the cyst.

Most of the ovarian tissue in the region of the tumor as replaced by tumor tissue. Areas of necrosis and hemorrhage are rather abundant, and throughout the section there as rich infiltration of lymphocytes, plasma cells, and few polymorphonuclear leucocytes. Some of the blood vessels contained recent thrombi, while others are invaded by tumor cells.

Stains for the presence of mucin gave negative results. Sudan III stain revealed many lipid droplets within the

tumor cells. Sections taken from tissues preserved in absolute alcohol and stained for the presence of glycogen (Best carmine) disclosed glycogen in the tumor cells.

These two tumors are evidently similar in every respect. It is clear that they resemble closely those seen in the kidney and classified as hypernephroid carcinoma, sometimes also referred to as renal carcinoma, adenocarcinoma with clear cells or malignant nephroma. As a matter of fact, several pathologists, not knowing that these sections were from an ovarian tumor diagnosed a kidney tumor. The most commonly accepted view is that such clear cell adenocarcinomas are true kidney tumors and do not arise from misplaced suprarenal rests within the kidney. These tumors must be differentiated from true hypernephromas, which, if they exist at all, are very rare. As Karner (3) stated, in order to identify a tumor as a true hypernephroma it seems necessary to find tumorous elements, such as may arise from the suprarenal medulla, the ganglioneuroma, the sympathicoblastoma or the pheochromocytoma. The hypernephroid carcinoma is characterized grossly by its yellow color and evidence of necrosis and hemorrhage. Histologically the large cuboidal or polyhedral cells with their clear cytoplasm, which may contain fat or glycogen, are quite outstanding. Early invasion of veins is common in these tumors. It must be emphasized that there is not a single recognized instance on record in which such a kidney tumor had caused changes in the secondary sex characteristics.

As has already been stated there are described in the literature yellow tumors in the ovaries which produce masculinization. These tumors are variously called lutenoma or lutein cell blastoma, hypernephroma and luteinized granulosa cell tumor. Recently the term virilizing lipid cell tumor was employed by Barzilai. Karner (3) stated that a tumor occurs in the ovary which looks like the cortical suprarenal adenoma and which is frequently but not invariably associated with masculinization. More recently such a tumor which did not produce masculinization was reported by van Kirk and Edwards. This tumor was called hypernephroma and it was stated that its cytologic structure suggested a hypernephroma rather than a lutein cell tumor. Histologically this tumor resembles closely the two tumors which we have just described and which we believe are "kidney tumors" in the ovary rather than suprarenal tumors and certainly not lutein cell tumors. They therefore, should be designated either hypernephroid tumors (resembling suprarenal tumors) or adenocarcinomas

with clear cells following the nomenclature which is used in the case of autochthonous kidney tumors.

Thus it is clear that there exist two different types of yellow ovarian tumors which morphologically resemble one another. The one which gives rise to masculinization is a true ovarian tumor. This is the lutein cell tumor (luteinoma, luteoma or luteinized granulosa cell tumor). Such a tumor has been previously described (4). In the case reported it was a soft, reddish-yellow tumor completely replacing the ovary. In many areas the cells of which the tumor consisted resembled those seen in the corpus luteum, while in other areas they resembled suprarenal cortical cells (See Fig. 7). Mitotic figures were seen very occasionally. There were many areas of necrosis, marked degenerative changes and hemorrhages. The tumor was richly vascularized. The patient had shown definite signs of masculinization which disappeared after removal of the tumor. It is evident that the two instances herein reported though grossly resembling this tumor are definitely different. Those yellow tumors which do not cause masculinization correspond to those encountered in the kidneys, but not in the suprarenal glands. From the accompanying illustrations, morphologic differences between these two tumors are apparent.

These tumors cannot be classified as papillary serous cystadenocarcinomas of either variety. They were not principally cystic, though occasionally papillary excrescences were noted. Stains employed for the detection of mucin gave negative results. Though clear cells may be found in so called seroanaplastic carcinoma of the ovary, the marked cellular variation, many atypical mitotic figures and formation of cysts and papillae are characteristic of this tumor. It is interesting to note that there are, however, tumors of this type which as Barzilai suggested resemble morphologically mesonephric structures. It is thus possible that some of the tumors which are classified as mesonephromas belong with those here reported and classified as hypernephroid carcinomas.

As has been stated, these two tumors histologically are identical with those so commonly encountered in the kidney. Though there is no proof it may be suggested that they have the same origin as true kidney tumors. As mentioned Schiller maintained that there are tumors in the ovary which may have a mesonephric origin. A search for structures within the tumor which could be interpreted to our satisfaction as true glomeruli was fruitless. However structures

somewhat resembling glomeruli were encountered here and there. As Simkins stated the mesonephric body produces an elongated ridge the urogenital fold which separates into a mesonephric and a reproductive part in the 7 millimeter embryo. The degeneration of the mesonephros ceases in the 21 millimeter embryo. Thus it is possible that during this period mesonephric structures may persist within the gonads and eventually give rise to tumor formation. It must be remembered that the mesonephrogenic masses differentiate caudally (Simkins) and form the true tubules of the mesonephric or wolffian body. As stated previously though tubules are rarely found in the tumors described by Schiller as mesonephroma, from the above it is clear that embryologically the occurrence of a tumor arising from tubular structures, identical with those seen in the kidney, can easily be explained.

SUMMARY

Two yellow obviously malignant tumors of the ovary are reported which in no way are related to those producing masculinization. These tumors were identical with carcinomas occurring in the kidneys. Such tumors when encountered in the kidney are designated either adenocarcinoma with clear cells or hypernephroid carcinoma (resembling suprarenal cortical structures). The same nomenclature should be applied to the identical tumors described here in the ovary. The mode of origin of such tumors in the ovary is discussed.

From this investigation and from the literature it seems that two types of yellow ovarian tumors must be distinguished each presenting a different histological picture. One causes masculinization and is either a luteinized granulosa cell tumor and may be called lutein cell tumor, luteinoma, etc. or if it arises from suprarenal cortical structures it is called hypernephroma. The other tumor does not produce endocrine disturbances and arises apparently from mesonephric structures within the ovary. This is the hypernephroid carcinoma or clear cell adenocarcinoma.

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RECONSTRUCTION OF WOUNDS OF THE COLON

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REPAIR of major disruptions of the colon in soldiers returned from combat areas presents problems seldom encountered in civilian surgery. Repair is rendered complex by the presence of wounds other than those of the colon wound *separatim*, debility of the patient, unusual locations of fecal fistulas, and extensive scarring.

Colonic fistulas in wounded soldiers are of two origins. One group comprising oostomies or colostomies performed because of intestinal injury is the more familiar. The most usual example is the double-barreled inguinal or transverse colostomy. In civilian practice this group presents no difficulty in repair because the surgeon is usually acquainted with the incident necessitating the primary surgical procedure and the anatomical and technical steps taken to accomplish the artificial anus. Military field records are necessarily brief and the details of construction of a colostomy may be scant or absent. As illustrated in several of our cases, it is dangerous to assume that a standard procedure has been carried out. The stress of time on a battlefield often necessitates modification of a usual procedure. This aspect must always be kept in mind by the surgeon repairing the wound.

The second group is peculiar to military action and comprises those fistulas resulting from wounds of the colon. This group presents the more complex aspects. There is always considerable loss of bowel wall. The artificial anus may be anywhere on the abdomen, the back, the flanks, the perineum, or the thighs. The wound may be infected. The defecating colonic stoma may be withdrawn into the abdominal cavity and lost to sight. General debility and extensive local scarring are usual results of this type of wound.

Sixteen disruptions of colonic continuity have been under treatment at the Lovell General Hospital. Of these, the first 11 disruptions have been repaired for 3 to 6 months and can be evaluated. The procedures employed in these cases have been identical and comprise the material for this discourse. We are continuing in the same fashion with all similar cases with no untoward results thus far.

If a student in anatomy were given a cadaver with a disrupted colon and told to restore the

bowel to anatomical continuity he would proceed in the following fashion. He would open the abdomen, mobilize the bowel ends within the peritoneal cavity, excise all scar tissue, restore the viscera to anatomical correctness, do a primary end-to-end anastomosis of the bowel loops, and close the wound. This is the simplest solution to the problem. This is what we have done.

To accomplish this ideal and simple solution of bowel reconstruction it is necessary to consider three aspects: (a) mobilization of the bowel, (b) anastomosis of the ends, and (c) closure of the wound. The line drawings depict the 11 colonic disruptions in 8 soldiers as they entered our hospital.

Mobilization of the bowel. In several of the patients (Cases 1, 4, 6) it was readily apparent that to approximate the bowel ends for any type of closure, it would be necessary to do an extensive intraperitoneal mobilization of the ends. In others, the external appearance of the colostomy seemed to warrant the use of a spur crusher and the conventional methods of closure. The use of a spur crusher is an excellent maneuver when the anatomy is a matter of record, and the surgeon can proceed with confidence. The necessity for crushing the spur of a colostomy prior to closure of the colon has been emphasized (3, 7, 13). The spur has been excised by some (6).

In disruptions of the colon due to war wounds, the anatomy found after exploration of the loops has demonstrated the danger of any procedure other than one involving complete investigation of the area of the bowel involved. In Case 5 the bowel loops were rotated through 180 degrees with the loops approximated along the line of vascular supply. *Crushing of the spur* also would have crushed the blood supply with a sure result of gangrene or hemorrhage. In Case 2 approximation of the loops along the vascular supply resulted from exteriorizing the ascending colon and cecum through a McBurney incision. In Case 6 the loops were sharply angulated laterally with adherent small bowel.

Earlier writers dealing with operations upon the open colon have repeatedly warned against opening the peritoneal cavity and spreading infection (1, 2). Relatively recently Rankin mentioned that it is undesirable. This viewpoint has been modified by the use of the various sulfona-

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mides (14) Poth and his associates have pointed out the increased safety of colonic surgery secured by preparation of the patient with succinyl sulfathiazole. The old contention that a colostomy provides peritoneal immunity to infection has been investigated by Collier Ransom and Rife (4) who conclude that although previous operations on the colon do promote some degree of resistance to infection on the part of the peritoneum it is not marked and of relatively short duration (little more than 1 month). They suggest that walling off of the peritoneal cavity by adhesions is probably a more important factor in limiting peritonitis. The presence of extensive adhesions in our cases was a favorable factor.

Anastomosis of the bowel ends. Primary anastomosis of the large bowel has received considerable attention in the literature of late. Metheny states that the principal cause of failure in the anastomosis of large bowel is gangrene caused by impaired circulation at the suture line. He corroborates the contention of Lockhart Mummery that successful end-to-end anastomosis is possible only when the ends of the colon have been cut to form an angle of 45 degrees at the mesenteric border to preserve the blood supply of the antimesenteric portion. Compliance with this postulation would result in an angle of 90 degrees between the loops of the anastomosis. The fulcrum of the angle being at the mesenteric attachment greatest stress would be thrown on the antimesenteric sutures. The mechanical difficulties of this arrangement have been pointed out by Warwick. We have assumed that tissue which is living and healthy will heal if the hazard of infection is minimized. Consequently, colonic ends have been cut across at right angles to the longitudinal axis of the bowel prior to anastomosis.

Closure of the wound. The closure of the abdominal wall in open colonic surgery has also received considerable attention in recent literature. As late as 1940 Pemberton and Black stated that "infections should be common in wounds after closure operations, because contamination from the colonic stoma at the time of operation cannot be avoided."

Collier and Valk (5) pointed out the high degree of successful healing possible when therapeutic colostomy wounds are packed open with vaseline gauze for 24 hours. We have adopted their method with the exception of waiting 48 hours instead of only 24 before tying the previously inserted silkworm-gut sutures. This was done because of the lower degree of resistance to infection believed to exist in the extensive scar tissue we were usually handling. In addition we used

crystalline sulfonamide in the wound. Pemberton and Black (9) also used the delayed method of closing colostomy wounds with success.

Collier and Valk (5) ascribe success in the delayed closure of contaminated wounds to the observation that fibrin exuded from the wound edges has been coagulated so that when the wound surfaces are brought together a more unfavorable environment is present for the bacteria in the wound.

The 8 cases herein presented have all had successful primary intraperitoneal end-to-end anastomosis of serious colonic disruptions and primary healing of wounds by delayed closure. Case summaries are presented. Details of preparation and operation were all the same except where mentioned and are discussed in detail later.

CASE 1. Private First Class, aged 33 years, received multiple machine gun bullet wounds of the chest and abdomen at close range on February 26, 1943. The most severe damage was sustained in the left upper quadrant, resulting in an almost complete disruption of the transverse colon. A colostomy was established at the site of injury and was complicated by the formation of a huge abscess, which subsided after drainage.

On June 24, 1943, he was received at Lovell General Hospital in fair condition. About half of the feces were passing per rectum. Much of the left upper abdominal wall was replaced by hypertrophic rigid scar centered about a 4 centimeter opening discharging feces and in which colonic mucosa was visible (Fig. 1). The scar for 3 or 4 centimeters surrounding the fistulous opening was red, tender and weeping a thin purulent exudate. Further examination disclosed that the transverse colon was in continuity in its mesenteric half but a large defect due to loss of substance was present in the antimesenteric wall. Adherence to the scarred anterior abdominal wall had partially plugged this considerable defect, leaving the fecal fistula as described. The distal colon was patent. The wounds in other portions of the body had healed.

The colon was repaired on July 7, 1943 with primary healing of the bowel. The defect was so large that in effect an end-to-end anastomosis was done. On the third day after operation, the soldier started himself on a low residue diet and bowel movements began on the fifth day. The low grade infection in the scarred upper abdomen promptly subsided so that at the time of tying the silkworm-gut sutures, the wound looked quite clean. On the tenth and twelfth day after operation, the silkworm-gut sutures were removed. A thin, purulent discharge persisted from the angle of the wound until the fourteenth day but the wound healed solidly and cleanly. Bowel function continued normal. There was occasional vague transient upper abdominal distress. The soldier gained 25 pounds in the next 3 months. Barium enema on September 10, 1943 visualized a normal colon. The soldier was discharged from the hospital on September 21, 1943.

CASE 2. Private, aged 27 years, wounded in combat in North Africa on April 1, 1943. Shell fragments tore a 3 inch by 3-inch wound in the left femoral triangle, then passed upward lacerating the bladder and sigmoid colon, and fracturing the ramus of the pubis. Within 12 hours, the badly lacerated sigmoid colon was exteriorized as a colostomy and the bladder was repaired. A total urinary fistula developed in the left groin. Some feces continued to

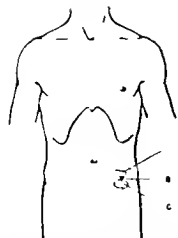


Fig. 5 Case 5. A Proximal end of distal loop. B bridge of skin. C defecating stoma. Note: Attempt is made to show that the loops of bowel are small and entirely turned 90 degrees.

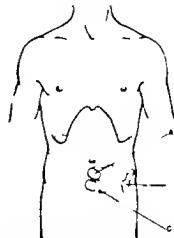


Fig. 6 Case 6. A Defecating stoma of double barrel colostomy. B proximal stoma resulting from high explosive wound. C distal loop of colon. Note: Both loops of bowel are sharply angulated to left beneath abdominal wall.

solid union of the fractures as evident. The sigmoid colon was reconstructed on October 22, 1943. Both loops were freed; laparotomically rotation as corrected, and an end-to-end anastomosis; thorax clamps as performed. Four grams of sulfanilamide and sulfathiazole (75% 5%) as sprinkled on the abdomen. The peritoneum as closed immediately and the abdominal wall after 48 hours. Healing occurred per primam and normal bow of movement began on the fifth day after operation.

By February 1944 patient as vigorously ambulatory weighing 50 pounds, with normal bow of function. Barium enema revealed normal colon.

Case 6. Pri at aged 3 years, as occurred to combat in Sicily on August 1943. Mortar shell fragments perforated the left groin and sigmoid colon with wounds of exit in the left lower back. The sigmoid colon as externalized in lower midabdomen; it sat of almost complete division, 8 hours following injury. It developed draining parastomal sinus; the left groin and iliac fossa and thrombophlebitis of the left leg.

On admission at Lovell General Hospital on September 8, 1943, examination revealed an emaciated male 66 inches tall and weighing 65 pounds. There as large purulent draining sinus in dense scar tissue just medial to the left anterior superior iliac spine (Fig. 6). A granulating sinus 3 centimeters in diameter as present in the left lower back just above the wing of the left ilium. In the midline of the lower abdomen, an irregular 4-centimeter colostomy sinus as present. Digital exploration found this to be double-barreled affair; the both loops angulated acutely beneath the abdominal wall toward the left. Fecal contamination in and about the parastomal sinus was evident. There as marked induration and tenderness in the soft tissues of the left iliac fossa with disability of the hip. The hip joint as not involved.

X-ray studies demonstrated fractures of the left ilium with multiple metallic fragments scattered throughout the left iliac fossa. Lipiodol injection of the purulent sinus found no connection with the intestine but extended deeply toward the ilium and bony gutter. There as no obstruction in the colon distal to the colostomy.

On October 8, 1943, the purulent sinus as explored and bits of shrapnel and clothing deep in the iliopectus muscle

are removed. Following this, the previously present fever abated, the drainage decreased but did not entirely cease. The colostomy was closed on November 9, 1943. Both loops are directed free in the peritoneal cavity and as end-to-end anastomosis without clamps as done. Convalescence was uneventful with bowel movements beginning on the fifth day after operation. The wound healed per primam; the sutures were removed on the tenth day and the patient was allowed out of bed on the twelfth day.

On March 1944, days following closure of the colonic wound, barium enema demonstrated normal colon, the patient as up and about and weighed 54 pounds. There as only slight drainage from the left iliac fossa and slight disability of the left leg.

Case 7. Private aged 2 years, On December 7, 1943, while unloading freight in Iceland, soldier was straddling the gunnle of the boat with his right foot on the dock. A donkey ran back into his right leg and the result as extensive severe, deep lacerations of the perineum, rectum, and left groin with multiple compound fractures of the pelvis, and severe crush injury of the right foot. On the day of injury all wounds are debrided. He received sulfanilamide locally and sulfadiazine by mouth, and multiple blood and plasma infusions. A pelvic celiotomy high developed as controlled by these measures. A left inguinal loop colostomy was done on January 6, 1944. He then gained enough to be evacuated to the Continental United States.

On admission to Lovell General Hospital on April 2, 1943, examination showed an emaciated 112 male, 66 inches tall, weighing 65 pounds. There was an extensive granulating wound of the perineum, transecting the sphincter anal, extending up into the rectum and into the left groin. An incompletely transected loop colostomy as flush with the skin level in the left lower quadrant of the abdomen (Fig. 7). The bowel distal to the colostomy was packed with feces. Most of the right foot was gangrenous and ulcerated.

On April 28, 1943, midcalf amputation of the right leg as done with satisfactory convalescence. Because of the continued discharge of feces into the perineal wound, Devine excision colostomy was done in the transverse colon on July 26, 1943. Healing of the perineal wound

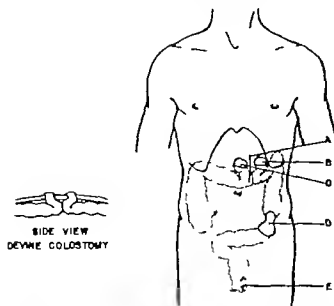


Fig. 7. Case 7. A Operative scar B, distal loop of Devine colostomy C defecating stoma of Devine colostomy D loop colostomy of sigmoid colon E, scar and deformity of anus and rectum due to wound.

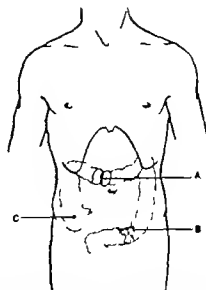


Fig. 8. Case 8. A Double barrel colostomy B obstructing carcinoma, C fecal fistula resulting from cecostomy loop colostomy in transverse colon followed by resection of carcinoma and end-to-end anastomosis of colostomy

ensued and a plastic repair of the rectal sphincter was done on October 29, 1943. On December 8 the left sigmoid colostomy was closed and on December 30 the transverse colon was reconstructed. Both colostomies were closed by an intraperitoneal end to-end anastomosis without the use of clamps. Operative incisions were closed 48 hours after completion of the bowel procedure. All wounds healed *per primam*.

On February 25, 1944, the soldier was up and about with normal function of the bowel and anal sphincter. X-ray films demonstrated a slight constriction in the transverse colon at the previous site of the Devine colostomy. No symptoms of bowel dysfunction were present.

CASE 8. Sergeant, aged 32 years, developed symptoms of intestinal obstruction on June 24, 1943 while in a combat area. On June 29, a cecostomy was done, at which time a napkin ring carcinoma of the sigmoid was found. He was transferred to this country by airplane and en route the tube came out of the cecostomy and he again developed intestinal obstruction.

Physical examination on August 7, 1943, when admitted to Lovell General Hospital, found an acutely ill white male, 67 inches tall and weighing 137 pounds. The abdomen was moderately distended. There was a recent right rectus operative incision, and just to the right of the lower end was a small sinus draining a few drops of fecal material (Fig. 8). Flat x-ray plate of the abdomen was diagnostic of intestinal obstruction.

After establishing fluid and electrolyte balance, a completely transected loop colostomy in the transverse colon was done on August 9, 1943. The patient did well. Barium enema demonstrated a constricting lesion of the sigmoid. On September 6, 1943, a resection of the adenocarcinoma of the sigmoid colon was done with an end to-end anastomosis. An intraperitoneal end to-end anastomosis of the colostomy was done on September 3, 1943. Both wounds were closed in 48 hours by the delayed method with primary healing. X-ray films of the colon demonstrated a normal contour. Since no metastases were demonstrated, he was discharged from the hospital in late November to be re-examined every 3 months for 2 years.

PREOPERATIVE PREPARATION

In general, a soldier is considered as a candidate for reconstructive surgery when he is gaining weight. To effect this end we literally stuff the patient with a high protein red meat diet and supplementary vitamins. Blood and plasma transfusions are given, of course when needed. We also give whole blood empirically as a stimulator to all patients prior to major surgery regardless of the hemoglobin and plasma protein values.

The anatomy and condition of the large bowel is investigated as completely as possible by roentgenography and endoscopic examination. All sinuses are investigated by lipiodol injection and x-ray visualization.

Both the afferent and efferent loops of bowel are irrigated daily with about a liter of 1:4000 potassium permanganate solution. This serves several purposes. It keeps the distal loop free of accumulated feces and mucus. Also it tends to maintain tone and caliber of the distal bowel and of the anal sphincter. Great care must be exercised that all barium is immediately washed out of the distal loop following an x-ray examination. If this is not done, a concretion forms quickly which is difficult to remove by irrigation and if left *in situ* jeopardizes an anastomosis proximal to it.

If the fecal fistula is feeding an infection of the abdominal wall (as in Cases 1 and 4) the use of an anterior Bradford frame to promote constant evacuation of feces and to eliminate the fecal poultice incident to a gauze dressing of a wound is invaluable.

SUMMARY

Balloon kymograph records of the motility of the human small intestine were taken before and during 11 abdominal operations.

In patients receiving the usual preoperative medication spinal anesthesia did not increase the ability of the small bowel to contract against a mild distending force.

The results suggest that under certain conditions spinal anesthesia is not a very potent means of stimulating human small intestinal motility and furthermore that its effect on the small bowel is abolished by moderate doses of morphine and scopolamine.

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SURGERY Gynecology and Obstetrics

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TREATMENT OF URINARY INFECTIONS OF CHILDHOOD

THE recognition that bacteria are the cause of urinary infections penetrated rather slowly into the practice of pediatrics and urology. The first micro-organism causing a urinary infection of childhood was isolated by Escherich; it was a colon bacillus which under the accepted bacteriologic nomenclature goes by the name of *Escherichia coli*.

Later it became evident that a number of bacteria can produce infections of the urinary tract, that these bacteria differ in their susceptibility to various antiseptics, and that different strains of the same micro-organism may do so.

Earlier acidification and alkalinization of the urine had been advocated by Bokai for the treatment of pyelitis of children. The reaction of the urine was measured by means of litmus as indicator. Such crude determinations were found inadequate. With the aid of the determination of the hydrogen ion con-

centration it was shown that a pH of 4.6 on the acid side and a pH of 9.0 on the alkaline side were necessary to sterilize a urine infected with a given colon bacillus. Such reactions are hardly obtainable *in vivo*. With the introduction of methenamine (urotropin) as urinary antiseptic the importance of the hydrogen ion concentration in the urine became emphasized. Methenamine itself is without bactericidal power but when the hydrogen ion concentration falls to a pH of 5.5 or less formaldehyde is liberated and displays bactericidal potency.

Often no attention was paid to this necessity of acidifying the urine sufficiently and then the medication was not successful. With acidification the dosage required produced irritation of the bladder in some cases with hematuria.

From 1894 to 1931 numerous urinary antiseptics were introduced such as phenyl salicylate (salol), pyridine hexylresorcinol and many others none of which in carefully controlled clinical tests, displaced methenamine, which remained the best urinary antiseptic of the time. Properly used it is still a very useful drug in any type of infection.

Helmholz and Clark introduced the ketogenic diet for the treatment of urinary infections. Betaoxybutyric acid is excreted by the human kidney in high enough concentrations to sterilize the urine when it has the proper pH. The lower the pH the lower is the concentration of the acid necessary to kill bacteria. So with a urine of pH 5.0 25 per cent of betaoxybutyric acid is bactericidal at pH 6.0 25 per cent and at pH 7.0 25 per cent are bactericidal. A pH of from 5 to 5.5 and a concentration of 1 per cent of the organic

acid are readily obtainable therefore one can easily obtain a bactericidal urine which affects all the bacteria found in acute urinary infections.

The introduction of mandelic acid by Rosenheim made it possible to give an organic acid by mouth rather than to produce it by a high fat diet. Mandelic acid too is bactericidal only at a pH of 5.5 or less in concentrations in the urine which can be achieved without danger of renal irritation.

With all three drugs it is necessary to have a certain concentration of the drug in the urine as well as a definite pH. These three drugs can be used successfully in all infections in which the kidney can secrete a urine of low pH together with a sufficiently high concentration of the drug. They are of no value when the kidneys are damaged and cannot perform these functions, and also in cases in which a strongly ammoniacal urine is produced by urea-splitting bacteria.

A further handicap to treatment is that the pH of the urine must be controlled, and this is not always easy although the method of testing it with nitrazine paper is simple enough.

The most recent addition to the group of urinary antiseptics is the sulfonamide compounds. Their rapid excretion even by the damaged kidney their action in acid and alkaline urine and their bactericidal action when given in small amounts that are not

likely to produce renal damage make them the urinary antiseptic of choice. However the great drawback of the entire group is their lack of action on *Streptococcus faecalis* infections.

This has introduced for the first time the absolute necessity of determining the nature of the infection. Hitherto certain bacteria might be slightly more resistant than others but could be got rid of by slightly longer treatment or by increasing the dosage. *Streptococcus faecalis* grows luxuriantly in urine containing one of the sulfonamide compounds in concentrations which will kill off the usual gram-negative bacilli. Since the introduction of the sulfonamide compounds it has been realized how frequently mixed infections of gram-negative bacilli and *Streptococcus faecalis* exist. Initial cultures may show apparently pure cultures of gram-negative bacilli but after several days treatment with one of these drugs pure cultures of *Streptococcus faecalis* may be found.

Of the sulfonamide compounds, sulfathiazole or sulfadiazine is the drug of choice in all but *Streptococcus faecalis* infections. In *Streptococcus faecalis* infections mandelic acid is the drug of choice. This leaves without adequate treatment only infections with *Streptococcus faecalis* in patients who have damaged kidneys, since neither the required pH nor the required concentration may be obtainable.

HENRY F. HELMHOLTZ

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

BELL'S *Textbook of Pathology*¹ has undergone several revisions since the first edition was published in 1930 and was last reviewed in these columns in the second edition in 1935. It was originally a work of collaboration by members of the faculty of the University of Minnesota, including E. T. Bell, B. J. Clawson, Hal Downey, J. S. McCartney and C. J. Watson.

The chapter on diseases of the urinary system was thoroughly revised in the fourth edition. The chapters on renal disease remain essentially unchanged in the fifth edition and are probably the best to be found in any textbook. Two new color plates have been added to this section illustrating by photomicrographs of the glomeruli various phases of glomerulonephritis. Although the plates adequately demonstrate the lesions one might conceive that students who are accustomed to seeing blue nuclei against a red background might find it difficult to interpret the reversal of colors in these plates especially since the method of staining is not recorded. Similar photomicrographs of glomeruli in black and white are included in the text which are equally clear if not more so.

The book is unusually well illustrated, containing 448 engravings and 4 color plates. Fifteen older illustrations have been removed and 32 new ones added in the fifth edition. All are of uniform excellence both in regard to choice of material and clarity of detail, and many of them are not to be found elsewhere. In keeping with the spirit of the volume they give the maximum information for the space they occupy. Brief additions have been made to the subjects of shock, vitamin deficiencies, blast injuries, Boeck's sarcoid and several infectious diseases related to war medicine to bring these up to date. The paper in this edition is thinner and less heavily coated than in previous editions; however it is of good quality and adequately displays the illustrations. The use of narrower margins and lighter paper do not detract from the appearance of the book and might be considered an improvement in reducing the bulk of the volume.

The material on general pathology is well handled and adequate space is given to the physiology, histology and anatomical anomalies of the organs at the head of each chapter in the section on special pathology. Practical clinical observations are numerous. Of particular interest to the clinician are Bell's outline of the clinical diagnosis of breast tumors and an excellent brief discussion of the

value of the biopsy and how it should be performed. Occasional minor typographical errors were noted. Sebrill is misspelled twice on page 44. Lymphocytic is misspelled in the subtitle on page 501. Plasmacytoma is misspelled twice on page 324 and the wrong page reference is given in the index under *Cushing's Syndrome*.

In spite of the brevity of the paragraphs one is constantly surprised at the amount of factual, useful information which has been incorporated into so small a volume. The book is practical, concise and objective and the material is presented in a clear, logical, outlined form. Well chosen references are conveniently included in the text with titles to facilitate their use. The book is highly recommended to the student and practicing physician both for study and reference.

DONALD O. MANSBARDT

IN writing his book² Dr. Christopher has performed a most useful service for the medical student, the surgical interne, the general practitioner and the experienced surgeon. He has moreover provided an example that can be emulated with profit by those who have in mind the writing of medical textbooks. This reviewer began the reading of the one thousand page volume entitled *Minor Surgery* with misgiving, continued with increasing interest, and finished with enthusiasm. The secret lies not in the skillful writing, the detailed and authoritative discussion of thousands of surgical problems, but in the method. In the preface the author modestly states:

—no one man can any longer be experienced in and informed regarding the entire field of surgery. Accordingly a thorough and painstaking analysis of thousands of current surgical articles has been made and the most valuable material condensed and made readily available. Many direct quotations are used because they offer the most accurate method of presenting the ideas of surgical experts and authorities and because they furnish the fairest method of giving these men credit for their work. All this is true but more is accomplished. No better way could be devised for introducing the medical student to the best surgeons of the day, their best work, and their sometimes divergent views regarding surgical practice. Independent thinking is thus stimulated, the basis of surgical research made evident, and any tendency to dogmatism nipped in the bud.

The survey of current surgical literature has indeed been thorough and the first six chapters

¹TEXTBOOK OF PATHOLOGY. Edited by E. T. Bell, M.D. 5th ed. Philadelphia: Lea & Febiger. 944

²MINOR SURGERY. By Frederick Christopher, S.B. M.D. F.A.C.S. 5th ed. Philadelphia and London: W. B. Saunders Co. 944

present the best picture of modern ideas and methods in the treatment of wound and burns that is available. There follow chapters on circulatory disturbances and gangrene, injuries and infections of the head and neck, tumors, diseases of the genitourinary organs, anal canal and rectum, and injuries and infections of the extremities. The chapters on preoperative and postoperative care are of especial value. Detailed instruction is provided on water and mineral balance, the nutrition of the surgical patient, the prevention and treatment of surgical shock, and of the more common postoperative complications. The concluding chapter is devoted to the surgical internist and contains much practical instruction that is all too often overlooked. This is the best book in its field.

LESTER R. DRAGSTEDT

THE manual by Alfred de Lorimer on roentgen diagnosis of the arthropathies presents a rather

THE ARTHROPATHY SERIES. HANDBOOK OF ROENTGEN DIAGNOSIS. By Alfred A. de Lorimer. A.B. M.A. M.D. Chicago: Year Book Publishers, Inc. 1943.

unique method of approach, with emphasis on visual education instruction. The arthropathies are divided into the osteoarthropathies and the true arthritides, the former associated with stress, the latter with protein reaction, toxic or bacterial invasion.

These general heads are subdivided into closely related groups. Each chapter covers a group beginning with a list of synonyms, then giving a description of the roentgen findings early and late stages, and especially the soft tissue reaction. Then the author discusses the corroborative roentgen findings and makes concise remarks on incidence, age, sex, usual sites of involvement, and occasionally brief mention of history, physical findings, and clinical course. Each chapter ends with a well selected group of references.

The numerous illustrations are excellently reproduced, the only feature meriting any criticism being the somewhat laudably devious lines markings ending in arrows which point to the important phases of each roentgenogram.

JAMES T. CASE.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgments must be regarded as sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

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EXPERIMENTAL STRUCTURAL ALTERATIONS IN THE BRAIN DURING AND AFTER CONCUSSION

W F WINDLE Ph.D R. A. GROAT Ph.D., and C A FOX, Ph D Chicago, Illinois

THE literature of brain concussion is voluminous but this is a deceptive indication of the number of constructive investigations undertaken. It is surprising that relatively so much of a purely metaphysical nature has been published on this vital topic and astonishing that a good deal of it is still accepted and quoted uncritically.

Concussion is a transient state which sets in immediately upon application of an adequate force to the brain. Its chief functional manifestations are unconsciousness and paralysis of certain neural components. Its histopathologic counterpart is a subtle intraneuronal disorganization which will be described here for the first time. The period following subsidence of the functional alterations of concussion should be called postconcussion. In it occur morphologic perhaps also functional sequelae of concussion.

In many head injuries concussion is combined with traumatic interstitial hemorrhage, contusion or laceration of the brain. The latter three types of injuries should not be given the unmodified designation concussion.

From the Institut of Neurology Northwestern University Medical School.

The work described in this paper was done under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and Northwestern University.

For preliminary reports see Windle, Groat, and Fox (4).

nor should the several post traumatic conditions be referred to loosely as concussion. In discriminate use of the term concussion and its equivalents has produced much confusion in the realm of traumatic brain injuries and their sequelae. Whatever the true distribution of cause and effect in this state of affairs the fact is apparent also that certain fundamental questions have received little serious attention in the experimental laboratory.

The purpose of the present investigation was to try to demonstrate a structural basis for the physiologic manifestations of pure concussion (8 to 24) and to correlate with these findings the histopathologic picture in post concussion.

MATERIALS AND METHODS

The guinea pig was chosen for the experimental animal because some knowledge of its brain had been gained previously in a study of asphyxial changes (25) and because the brain is not too large to be serially sectioned and stained. Young adults weighing 300 to 400 grams were selected. The experimental series consisted of 36 specimens receiving concussions. For control 14 normal animals were paired according to size and sex with 14 of the experimental animals and received the same treatment except for concussion. All served for functional comparison and



Fig. 1



Fig. 2

Figs. 1 and 2 Large tegmental cells from the brain stem of a normal control guinea pig Magnification 278X



Fig. 3

Figs. 3 and 4. Four large tegmental cells from the brain stem of a guinea pig which received a concussive blow and was killed by perfusion with formalin a few seconds later. Disorganization of the Nissl-body pattern



Fig. 4

can be seen. The cell pictured on the extreme right shows that some agglutination of the fragmented Nissl bodies and hyperchromatic staining had occurred. Magnification 278X

ing 2 which received only single light sub-concussive blows showed definite cytopathologic changes in the brain which appeared to be the direct result of the blows. The cell changes after the first day were similar in all specimens varying only in extent and intensity with the severity of the blow and the time after striking it. Although they were observed in neurons of all sizes large cells, such as those of the red and lateral vestibular nuclei demonstrated the effects of concussion most clearly.

Within 24 hours after striking a strong blow upon the head disintegration of Nissl bodies i.e. chromatolysis could be clearly observed. The 4 hour specimen resembled those killed by blows (see page 566) but at 14 and 15 hours, disorganization of the Nissl body pattern and even beginning lysis could be determined. Certain neurons of all the 14 hour to

1 day animals exhibited shrinkage and hyperchromatic staining. These were located among cells which showed beginning chromatolysis, in fact, they themselves showed disorganization of the pattern of Nissl bodies. By 2 days many cells showed marked changes reaching maximum intensity by the sixth or eighth day. Progressive chromatolysis, like that illustrated in Figures 6 to 15 culminated in destruction of some neurons not all were affected so severely. Within a group of functionally similar nerve cells 6 to 8 days after concussion some were so badly damaged that they could scarcely be expected to survive (Figs. 13 and 15) while others were only moderately affected and many were entirely normal in appearance even after the most severe blows. About half the cells of a nucleus was the greatest proportion affected in any experiment (Figs. 16 and 17)



Fig 5

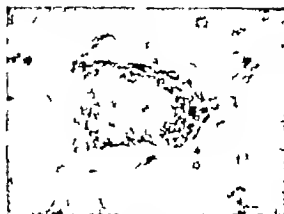


Fig. 6

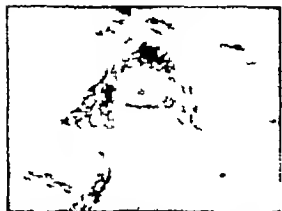


Fig 7

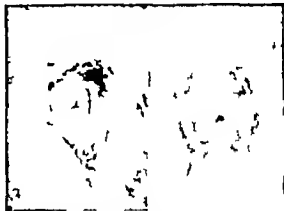


Fig 8

Figs. 5 to 8. Large tegmental cells from the brain stem of guinea pigs receiving concussive blows 24 hours previously

The beginning of chromatolysis is illustrated in these six cells. Magnification 275X

Critical comparison of the chromatolytic picture after concussion with that after transection of nerve fibers, i.e., the axon reaction, and after asphyxia revealed significant differences. After sectioning the axon near the cell body chromatolysis could not be observed until the end of the second day after concussion it could be detected at 14 hours and after asphyxia the cytoplasmic changes preceding a true chromatolysis were seen as early as 3 hours. After axon section, chromatolysis began as a breaking up of Nissl bodies around the nucleus and in the cytoplasm adjacent to the axon hillock. After asphyxia, it was frequently initiated as a peripheral clear zone with subsequent vacuolization at the periphery and over-all lysis as early as 30 hours. Concussion on the other hand, led to

a more uniform alteration of the chromatic substance in the early stages. Comparison of Figures 18 to 21 reveals the differences between axon reaction asphyxial and concussion changes commonly found. Eccentricity of the nucleus, a frequently encountered feature of chromatolysis in the axon reaction was only occasionally evident after concussion and asphyxia. These and other observations suggested that, whatever the reason for chromatolysis after concussion it is not asphyxia or primary damage of nerve roots and tracts leading to the axon reaction.

Other evidence was brought to bear upon this question. Sections from brains of severely concussed animals killed after 6 to 32 days were stained by methods for myelin sheaths and axis cylinders of nerve fibers. Nowhere

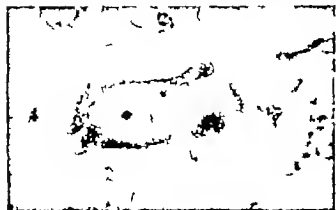


Fig. 9.

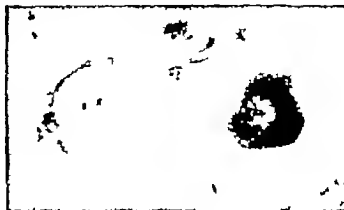


Fig. 10.

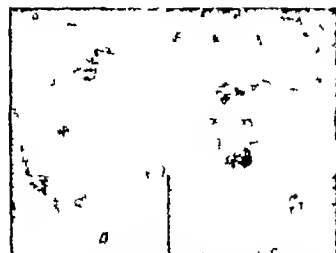


Fig. 11.



Fig. 12.

Figs. 9 to 12. Large tegmental cells from the brain stem of guinea pigs which received concussive blows 4 days previously. Marked chromatolysis is evident in five of the

cells which are illustrated. The one on the right in Figure 10, which is out of focus, was not affected. Magnification $\times 78X$.

was massive degeneration of fiber tracts seen. In the animals which were struck the most severe blows, a variable amount of swelling was observed in sheaths of nerve fibers in the lower medulla oblongata and upper cervical spinal cord. Lower reaches of the cord were less affected. Damage in the cord appeared to be confined to deeper parts of the ventral and lateral funiculi. The peripheral zone and the dorsal funiculi were spared. The axis cylinders of fibers appeared to be little, if any affected. Swelling of myelin sheaths was found as early as 2 days after concussion.

There appeared to be no close relation between the fiber damage and the cell change for there was no significant primary injury of nerve bundles or tracts in many brains which exhibited marked chromatolysis. Further more if the cytopathologic changes were due to tension upon the cranial nerve roots, they

should have been most marked in the motor nuclei of the brain and the sensory cranial ganglia because these are the sites of the cell bodies of the root fibers. The semilunar ganglia were left attached to most brains. Their cells were unaffected by concussion. Chromatolysis was observed in primary motor neurons of cranial nerve nuclei in only one instance of very severe concussion and there it involved only an occasional cell.

A direct approach appears to have given the clearest proof that certain nerve cells are the elements affected immediately in simple concussion. In 5 experiments it was certain that formalin reached the brain through its blood vessels 8 to 30 seconds (perhaps sooner) after the head had been struck. Comparison with nonconcussed controls stained at the same pH demonstrated significant alterations in arrangement, shape and size of

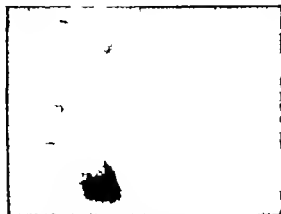


Fig. 3

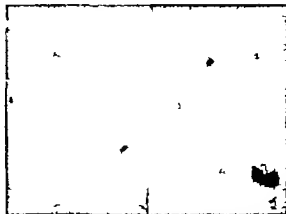


Fig. 4

Fig. 5

Figs. 3 to 5. Large tegmental cells from the brain stem of guinea pigs receiving concussive blow 6 days (Figs. 3 and 4) and 8 days (Fig. 5) previously. Extreme

degrees of chromatolysis are illustrated. A portion of relatively normal cell is seen on the left of Figure 5, somewhat out of focus. Magnification 578X.



Fig. 6



Fig. 7

Fig. 6. A low power view of the red nucleus 4 days after concussion of guinea pig. Note the large proportion of pale-staining, chromatolized cells. Magnification 90X.

Fig. 7. Dieter's nucleus from the same guinea pig as illustrated in Figure 6, 4 days after concussion. Magnification 90X.

Nissl bodies of many neurons of the same nuclei which were observed in chromatolysis a day or more after concussion. It seemed that the Nissl bodies of some cells were fragmented and disarranged by the blow. In other cells, their particles gave the appearance of agglutination. Many neurons remained unaffected. The changes in question are illustrated in Figures 3 to 5. Comparison with controls (Figs. 1 and 2) shows disturbances of Nissl body patterns. In 2 animals killed by

strong blows and perfused as quickly as possible similar changes in Nissl-body arrangement were encountered. Nucleolar changes were seen in many cells of animals living a day or less after concussion. Many of the Nissl body changes seen 14 hours to 1 day after the blow resembled those immediately afterward.

The amount of damage was proportional to the strength and number of blows. The greatest amount of chromatolysis followed multiple and single strong concussive blows.

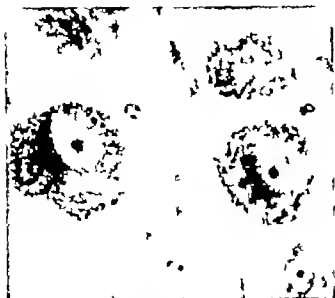


Fig. 18



Fig. 19.



Fig. 20.



Fig. 21

Figs. 8 to 2. Four photomicrographs to illustrate the differences between effects of sectioning the axon, asphyxiation and concussion. All are cells of the red nucleus. Figure 18 is from a normal control animal. Figure 19 is from a guinea pig in which the rubrospinal tract was

severed 4 days previously. Figure 20 is from an animal asphyxiated and resuscitated 4 days previously. Figure 21 is from an animal receiving a concussive blow 4 days previously. Figures 18, 19 and 21 are from young adult animals. Figure 20, a newborn. Magnification 278X.

A single subconcussive blow was ineffective in 2 of 3 animals but 2 subconcussive blows in 1 animal produced as much chromatolysis as a single light concussive blow in 3 others.

In no instance was destruction of neurons observed in the cerebrum, basal ganglia or cerebellar cortex. Some of the severely affected animals showed alteration of the Nissl body pattern of large pyramidal cells. These neurons exhibited thickening of nuclear membrane and clumping of Nissl bodies. The cells

stained darkly and only rarely could a hypochromatic cell suggestive of chromatolysis be found. The changes were not very marked in fact, they were not definitely identified until after we had examined sections from the cerebrum of monkeys which had received concussive blows. The cortical cells of monkeys are much larger than those of the guinea pig and consequently show the changes better.

In the guinea pig the main damage appeared to be confined to the brain stem and

spinal cord. Furthermore certain nuclei only were affected. All concussive blows induced changes in the lateral vestibular nuclei and the scattered large neurons of the tegmentum of the midbrain and pons and reticular formation of the medulla oblongata on either side of the median raphe. With increasing severity of concussion the red nuclei nuclei of the trigeminal spinal tract medial vestibular and cochlear nuclei became involved. In one instance 2 days after a very severe petechial hemorrhage unduring blow an occasional primary motor cell in the oculomotor and facial nuclei was found to be chromatolyzed. Otherwise no primary motor neurons of the brain stem were damaged. It was interesting that proximity to the ventricles was not a factor governing occurrence of damage.

Changes were observed in the spinal cord. Nearly all specimens which exhibited chromatolysis in the reticular formation of the medulla oblongata had a few cells affected in the posterior horn of the upper cervical segments. Those with more severe damage in the brain stem also showed marked spinal cord changes. In several animal neurons of the anterior horn were chromatolyzed in the cervical region although the posterior horns were more involved. A rather good correlation was drawn between severity of cytopathology and degree of motor disability in the first 2 days after concussion. The animal showing marked spinal motor weakness also exhibited the most structural damage in the spinal cord. Those which showed no motor symptoms on the second day had no chromatolysis in the anterior horn cells.

Control exhibited no chromatolysis. The axonal degenerating neuron found in normal adult brain was not encountered in the nonconcussed control guinea pig of the present series. These were young sexually mature animals which had not attained maximum growth. The animal which had received no anesthesia showed a much damage as those anesthetized.

Hemorrhage was an unimportant component of the pathologic picture after experimental concussion. Hemorrhages mostly very small and insignificant points of bleeding into the meninges or outside the dura mater

were encountered in a number of the guinea pigs after strong blows upon the head. Extensive meningeal bleeding occurred only in 2 which were killed by blows. Intramedullary hemorrhages were found in 4 specimens receiving very strong nonfatal blows. In 1 a few petechiae were located in the anterior thalamus hypothalamus, rostrum of the corpus callosum and upper cervical spinal cord. In the others, small interstitial hemorrhages were found in the cervical and thoracic spinal cord. The cytopathologic changes under discussion were never associated with hemorrhages.

No evidence of brain edema due to striking blows upon the head was observed in the histologic preparations. At no time after concussion did a marked glia reaction appear. After 1 week a limited proliferation of astrocytes was observed in the animal receiving the strongest blows but the microglia appeared to be no more numerous than in controls. In this respect as well as in absence of hemorrhage and lack of evidence of edema the histopathology after pure concussion was unlike that after asphyxiation (25).

DISCUSSION

Previous articles dealing with histologic changes in the brain after conditions designated as concussion have revealed variously no alterations cell changes, fiber changes and small hemorrhages. Every such study which has been found in the literature is open to criticism. On the face of the available reports it is impossible to arrive at any other conclusion than the vague notion that concussion involves widespread and generalized primary and secondary cell and fiber degeneration and hemorrhages. Against this is the view of other writers that concussion is purely functional with no anatomical substratum.

The haze lifts considerably with realization that in only one instance (8) have investigators discussing histologic changes in concussion defined the latter term. In all cases in which hemorrhages are described as part of the concussion picture it is clear that while such hemorrhages are an indication of the severity or peculiarity of the injury they do not necessarily bear further relationship to the condition of concussion that

may have occurred. The extensive 'Duret hemorrhages' which Berner (2, 3) has confused with concussion attest to the severity of the injury. Berner's material consisted of postmortem cases in which patients died as a result of head injury. But the injury was certainly not pure concussion. It was concussion plus traumatic interstitial hemorrhage. The former (in its true sense) as well as the latter may have been instrumental in causing death. Much the same comment applies to Neugebauer's work. Many of his patients were perhaps more intensely injured than Berner's and consequently the hemorrhages were somewhat more generalized in the brain stem. The excellent investigations of Schaller, Tamaki and Newman (20, 21) of the genesis and significance of multiple petechial hemorrhages are likewise beclouded by the unfortunate misuse of the word 'concussion' when the injuries clearly were complicated. Autopsy studies serving as the basis for elaborate theories of circulatory disorder in the so-called postconcussional state e.g. Friedmann and Rosenhagen are similarly vitiated by complications and doubtful concussion.

Reports of cell and fiber alterations are gapingly open to criticism (4, 6, 12, 15, 19, 22). The injuries were not concussion or were not described and hence cannot be evaluated as concussion; the methods used were inadequate and controls were lacking.

Nimier wrote of a single case of suicide by rifle bullet through the head as concussion. Whether a concussion existed or not he was unable to find microscopic lesions upon histologic examination of all parts of the brain outside the path of the bullet. Recently Denny Brown and Russell were unable to find evident microscopic lesions in the material from their acute animal experiments. These and other similar reports do not mean that there were no changes but simply that the nature of the examinations was such that changes were not revealed. The work of Koch and Filehne has been cited as evidence that concussion can occur without any anatomic changes but it is not clear that these workers used a microscope. Nor is it clear that the condition which they and others produced by striking many light rapidly re-

peated blows should be considered analogous to the concussion produced by one severe blow, whether this is the initial one or not.

The results of Jakob and of Brunner are the only ones which merit detailed discussion. Neither investigator defined concussion but Jakob did give descriptions of the gross functional effect of blows. In most cases these are sufficient to serve as a basis for characterizing the blows as concussive or nonconcussive. Jakob studied the central nervous system of 14 rabbits and 3 monkeys removed at various times after the animals received one or more blows on the fixed head. In the rabbit series he found no microscopic changes in 3 animals which died within 2 minutes after concussive blows were struck. Neither did he find changes in 1 animal sacrificed 24 hours after a nonconcussive blow. The remaining 10 animals received from 3 to 84 blows, the larger number being delivered over several days, and were sacrificed 6 to 81 days after the beginning of the experiment. The most constant alteration was degeneration of nerve fibers. Glia changes were quite regularly found. They were either regressive changes and proliferation or aggregation of debris-gorged glia in vessel sheaths. Nerve-cell changes were found in 6 animals from 6 to 59 days after the first injury. In 3 of these instances concussion had been sustained in 2 others it was doubtful and in 1 which received 29 blows it was absent. Of the remaining 4 rabbits 1 received 10 blows, no concussion was killed after 13 days and showed fiber degeneration; 1 received 3 blows, no concussion was killed after 31 days and was studied only for Marchi degeneration which was present; 1 received 5 blows, concussion was killed after 150 days and showed fiber degeneration; the last received 84 blows, no concussion was killed after 81 days and showed very many scattered small hemorrhages with softening of different ages and glia proliferation with ameboid glia present.

The fiber degeneration which Jakob found was heaviest in the medulla oblongata and cervical spinal cord particularly in the longer ascending and descending tracts. Above and below these regions it tended to grade off. Degeneration was visualized by the Marchi

method. The histologic reaction accompanying degeneration as shown by other methods, was described at length. The nerve cell changes were diffuse. In the two 6-day animals, for instance profuse chromatolysis was reported in all of the basal nuclei thalamus red nucleus pons, medulla oblongata and anterior horn of cervical spinal cord. It was especially severe in the cranial nerve nuclei of the medulla oblongata.

It is evident that Jakob's findings in regard to cell changes are at variance with those of the present work. Some of the discrepancy may be a consequence of the rather impractical method of inflicting injury which Jakob employed. Most however appears to result because Jakob's animals were not fixed by perfusion and because he did not use controls.

Jakob used 3 monkeys for concussion a fourth as control. The control died and the central nervous system was removed while the animal was still warm. All the monkeys received multiple blows, doubtful concussion and presented the complications of infection and malnutrition. They were killed 8, 16 and 44 days after the injury. Because of the complications which were aggravated after the injury Jakob felt that he could report only on the Marchi degeneration which was present as in the rabbits.

Brunner's primary interest was concussion of the inner ear. He used 7 guinea pigs striking repeated blows on the fixed head. The brain stem and cerebellum of 4 were studied histologically by a method for Nissl bodies only. One guinea pig was used as a control for these histologic studies. One animal was killed 2 days after sustaining 10 blows. Here there were glia changes, neuronophagia, and small hemorrhages in the tuberculum acusticum and degeneration of cells of the cochlear and vestibular nuclei. A second animal received 10 blows in 2 days and was sacrificed 4 days after the last. It was perfused. There were glia changes and light chromatolysis in the cochlear and vestibular nuclei especially in the medial vestibular and ventral cochlear nuclei. The small cells were the only ones so affected the large and medium sized neurons were normal. The third animal suffered 10 blows. Perfusion was performed but

the author stated that fixation was so poor that the distinction between pathology and artifact was difficult. Chromatolysis, glia changes and neuronophagia were seen with certainty only in the region of the large cells of Deiter's nucleus. The last animal was struck 15 blows and killed 74 days later. Small hemorrhages of old standing thought to be the result of diapedesis were found in the brain stem. Surrounding cells were unharmed. Widespread glia proliferation and chromatolysis of nerve cells were observed in the brain stem. Here again the findings differed from those of the present work and undoubtedly for the same reasons which were applied in the résumé of Jakob's work. True there was a control animal but the controlling activity apparently went no further than just that. Two of the experimental animals were perfused but the perfusion technique must have been inadequate since by the author's admission one of these was very poorly fixed.

A further criticism of Jakob's and Brunner's reports is their failure to relate anatomic changes of the postconcussion period to anatomic and physiologic changes of concussion. This correlation can be drawn in our work. Results of previously published physiologic studies are compatible with the currently reported concussion and postconcussion histologic findings. Groat Magoun Doy and Windle (10) observed that in brain concussion of the cat excitability of such supranuclear motor regions as the cerebral cortex, hypothalamus and brain stem tegmentum was decreased while functional alteration of cells of cranial motor nuclei was less constant and less severe. Nerve fibers in the brain rarely exhibited decreased conductivity. By comparison of certain reflex activity with the excitability of the corresponding motor cell group in the brain stem it was concluded that reflex inactivation in concussion was due primarily to interneuronal dysfunction.

Our inability to find marked damage of nerve fibers or their myelin sheaths after concussion can be correlated with lack of functional changes. Our physiologic studies demonstrating only slight and transient impairment of excitability of primary motor neurons are in full accord with the present

finding of little or no structural change in cells of cranial motor nuclei. The structural changes were indeed confined to interneurons which may be the reason for marked impairment of function shown by our physiologic studies.

Not all interneurons of the brain appear to be damaged by concussion. At least, we were unable to observe frank changes in all. This was notably true of the higher centers and the cerebral cortex. An effort was made to report damage only when by careful comparison with controls it seemed unequivocal. In many instances we could find neurons which we thought exhibited structural alterations but which in normal material, possessed irregular or indistinct Nissl body arrangements. That we may have been overly cautious has been demonstrated in the cerebral cortex. The larger pyramidal neurons in the monkey clearly showed changes after concussion (11) although examination of the same neurons in the guinea pig left a feeling of uncertainty. Little has been said of the small nerve cells. It is difficult to tell when they are affected because many have scanty Nissl material normally. Possibly careful cell counts in selected regions would reveal fewer small neurons after a week or two.

The present observation of immediate cell changes is so far as we have been able to determine, new. However it is not surprising to find disorganization of Nissl bodies especially the large flakes of large neurons in concussion. Others (1) have demonstrated that Nissl bodies have a structural representation in the unfixed nerve cell and can be caused to stratify by centrifugation. In our experiments these bodies did not become stratified but they apparently were fragmented and otherwise affected by the force applied. What is rather surprising is that not all nerve cells in a group of functionally similar neurons were equally affected by the blow. This is correlated with the fact that, later chromatolysis was found in only certain cells of a group.

The nature of the disability which lies at the bottom of the altered function in concussion can only be guessed, for the relation of the subtle immediate histologic changes to the functional phenomena is unknown. These histologic changes do serve as visible indicators of the

ravages of a concussional force and they mark the points at which postconcussional loss of cells will occur. The number of cells lost in postconcussion is probably only a fraction of the number functionally altered in concussion. It is reasonable to suppose tentatively that all the neurons are exposed to the concussive force to some degree that certain groups of cells are more susceptible than other cell groups and fibers and that depending upon their condition at the time of application of the force some of the susceptible cells are irreversibly injured. This number varies directly with the intensity and number of concussions but probably is automatically confined below a definite upper limit by the intervention of death if the immediate cell damage attains a certain lethal level. The part which the neuron loss might play in the post traumatic condition following pure or complicated concussion is debatable.

Though the word concussion has served only as a source of confusion in the past there is no reason why it should not be redeemed and employed to denote a discrete and specific, though transient pathologic condition. At least such would appear desirable pending additional information and experience. At some arbitrary state, concussion passes into postconcussion. Only in uncomplicated concussion can the functional course of this transition be seen. It is the time when the subject begins to react to incoming sensory impulses at all levels. It is only later in post concussion that frank degeneration of numerous nerve cells can be seen. The significance of the cytopathologic alterations of concussion and postconcussion has yet to be determined.

SUMMARY

Brain concussions were produced in guinea pigs by striking blows of graded intensity with a pendulum like apparatus. Most animals were lightly anesthetized with chloralose and were permitted to live for varying periods up to 32 days after concussion. The animals were then anesthetized with nembutal and killed by perfusing the heart with 10 per cent formalin. Brains and spinal cords were sectioned serially and prepared for histologic study. Staining was controlled

In a few experiments the brain was fixed by perfusion with formalin within a few seconds of the time a concussive blow was struck upon the head. Significant alterations in arrangement, shape and size of Nissl bodies of neurons were observed in these specimens. The Nissl bodies of some of the cells appeared to be fragmented and disarranged by the blow. In other cells their particles gave the appearance of agglutination. Many neurons remained unaffected. Similar changes were observed in animals killed by strong blows and perfused immediately as well as in others which lived for a day or less after the blow.

In less than 24 hours after concussion chromatolysis of certain neurons began. By 2 days many cells showed marked changes, reaching maximum intensity by the 6th or 8th day. Progressive chromatolysis culminated in destruction of some neurons but not all were affected so severely. Chromatolysis after concussion differed significantly from that observed after sectioning nerve fibers and that seen in asphyxia.

In most of the experiments, nerve fibers and myelin sheaths appeared to have received little if any damage. In those specimens which were struck the most severe blows a variable amount of swelling was observed in myelin sheaths, especially in the lower medulla oblongata and upper cervical spinal cord. There appeared to be no correlation between fiber damage and the cellular changes.

All neurons were not equally affected in concussion. Primary afferent and primary efferent neurons of the cranial ganglia and cranial nerve nuclei were practically unaffected. All concussive blows induced changes in the lateral vestibular nuclei and the scattered large neurons of the tegmentum of the midbrain pons and reticular formation of the medulla oblongata. With increasing severity of concussion the red nuclei nuclei of the trigeminal spinal tract, medial vestibular and cochlear nuclei became involved. Large pyramidal cells of the cerebrum underwent alterations but did not show chromatolysis. The basal ganglia and cerebellar cortex appeared to be unaffected. The amount of damage was proportional to the strength and number of blows struck.

Hemorrhage was an unimportant component of the pathologic picture in and after concussion. Rarely was intramedullary hemorrhage noted and meningeal bleeding occurred only in 3 animals killed by blows. The cytopathology was not the result of hemorrhage.

The cell changes observed in concussion of guinea pigs are in every way compatible with the functional observations in and after concussion of the cat. Studies in the monkey now in progress show similar results. All experiments were thoroughly controlled.

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INJURIES OF THE EXTREMITIES IN AMPHIBIOUS WARFARE

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THE treatment of war wounds is a subject of great interest at the present time as is evidenced by the large number of articles which are appearing in the medical journals and in the lay press. The conditions under which treatment must be carried out the wounds encountered the large number of patients who must be seen in a short period of time and the psychological reactions of men who have faced an enemy in mortal combat are a few of the factors which influence the treatment of patients wounded in battle.

The purpose of this paper is to present a statistical and descriptive study of patients who received injuries to the extremities while engaged in amphibious warfare. The management of these injuries and of the complications which ensued has enabled us to form impressions and to draw a few definite conclusions.

Of 984 consecutive battle casualties admitted to this hospital ship 638 or 64.8 per cent had sustained injuries of the extremities and were under observation for a period varying from a week to 10 days. The time elapsed between the moment of injury and the time of admission was variable and ranged from a few minutes to 4 days. The majority of patients were seen within the first 48 hours and 28.3 per cent were seen during the first 24 hours (Table I). The observations made on these patients form the basis of this report.

It has been necessary to bring all patients to the ship in small boats and to bring them aboard except in the case of ambulatory patients, on stretchers. On the quarter-deck each patient was seen by the embarkation officer who appraised the general condition of the patient and the nature and extent of the wounds before despatching the patient to a dressing station or ward where a medical officer awaited his arrival.

CONDITION OF PATIENTS ON ADMISSION

Inasmuch as many of these patients were admitted directly from the beach often within a few minutes of the time they were injured only the most necessary first aid had been given. Some of the patients had been painted with camouflage paste, many were covered with dirt often they were wet, and frequently they were plastered with blood and sand. In some instances as many as two extremities had been blown away (Fig 1) and tourniquets were in place. In other cases intracranial thoracic, or abdominal injuries accompanied the injuries of the extremities. Some of the patients with older injuries had previously received excellent treatment at other activities.

In patients with wounds of the extremities 571 (89.5%) were in good general condition on admission. They required no immediate transfusion of blood or administration of plasma. It was not necessary to take them to the operating room for the control of hemorrhage. It was frequently necessary to use morphine sulfate for the control of pain and this drug was given liberally in doses of $\frac{1}{4}$ or $\frac{1}{2}$ grain. The treatment of many of these patients could be deferred until the more seriously wounded were cared for. Some required only dressings while others had to be taken to the operating room later for necessary treatment.

Twenty two patients (3.46%) were in fair condition requiring plasma and blood transfusions without delay and 45 (7.05%) patients were in poor or critical condition immediately and energetic treatment being necessary in order to give them the maximum chance of recovery. Four in the latter group died soon after admission.

CAUSE OF INJURIES

Fragments from shells bombs grenades and mortars, and flying debris such as con

TABLE I.—TIME ELAPSED BETWEEN INJURY AND ADMISSION

Hours	Number of patients	Per cent of patients
to 24	8	28.5
24 to 48	245	38.4
48 to 7	83	3
7 to 96	30	30.5
Total	366	100

TABLE II.—CAUSE OF INJURY

Missile or agent	Number of patients	Per cent of patients
Fragments	366	57.8
Gunshot	3	.6
Fragments and gunshot	3	.90
Burns, bayonet, sword, operational	35	6
Total	368	100

Not counted

crete were responsible for the wounds in 366 patients, or 57.8 per cent of those wounded. The fragments recovered varied in size from minute particles to pieces weighing as much as a pound but we are inclined to believe that some of the contusions and fractures were inflicted by even larger pieces of concrete. Rifle and machine gun fire accounted for injuries to 36.1 per cent of patients and 3.9 per cent of the patients were wounded by both fragments and gunfire. Various other instruments of war such as thermal agents, bayonets and swords, caused the injuries of 6.1 per cent of patients (Table II).

TYPES OF WOUNDS

There is no satisfactory classification for wounds inflicted by missiles which vary so greatly in size, shape, velocity, temperature and consistency. Some of the patients had received sprays of small fragments and all

TABLE III.—LOCATION OF WOUNDS IN ORDER OF FREQUENCY

Part wounded	Number of those wounded	Per cent of patients
Upper arm	69	26.48
Lower leg	67	26.7
Thigh	57	14.60
Hand	26	9.74
Shoulder	23	3.00
Forearm	7	
Feet	50	7.83
Knee	38	5.94
Buttocks	18	5.95
Elbow	3	4.85
Total	930	100.00

TABLE IV.—PERIPHERAL NERVE INJURIES

Nerve	Number injured	Per cent of patients injured	Avoided palsy	Avoided complete	By Cast	By Cast	By Cast
Brachial plexus		3.77					
Radial	14	38.19	26	6	9	7	
Ulnar	6	26.94	2		7		1
Median	3	1.30	3		3	3	3
Sciatic	2	.81			2		
Lateral femoral cutaneous		3.77					
Common peroneal	5	.44		3			
Deep peroneal		3.77					
Superficial peroneal		.77					
Total	31	100.00	26	7	31	19	19

extremities were occasionally involved. These small fragments penetrated to different depths; some could be picked from the skin, some could be felt under the skin, and others were detected only on roentgenologic examination. In such cases it was unusual for the fragments to disrupt the blood vessels, nerves, or bones although the joints were occasionally involved. Many of these small wounds could be properly designated as puncture wounds.

Very rarely encountered were the cleanly cut lacerations. The skin edges were usually irregular in outline, ragged, dirty and some times burned. The involvement of the underlying tissues was not necessarily related to the size of the skin wound since the fragment may have turned and presented a smaller or larger diameter after penetration of the skin. As is well known in bullet wounds the wound of exit was larger than the wound of entrance although in some cases both wounds were

TABLE V.—INJURIES TO LARGE BLOOD VESSELS

Vessel	No cases	Caused by		Final result	Disposition
		Fracture	Gunshot		
Femoral					Amputation mid thigh Ligature Amputation
Popliteal					Amputation low thigh Amputation by ligature Ligature
Subclavian					Secondary hemorrhage controlled by suture
Total	9	9	2	2	

small and healed promptly. More than half (50 9%) of the wounds were 3 centimeters or more in diameter and many were as much as 400 square centimeters in area. In some patients large flaps of skin and subcutaneous tissue had been avulsed or turned back and in a few lacerations of the skin fascia and muscles, especially in the arm the buttocks, and thigh had resulted in large gaping wounds which gave the appearance of great foss of tissue. If the wounds involved the deep fascia or deeper structures they were classified as deep wounds and those in 72 5 per cent of the patients fell into this category. It will be shown later that injuries to bone were sustained by 36 83 per cent of the patients.

LOCATION OF WOUNDS

Statistical tabulation of the wounds showed that the lower and upper extremities were involved approximately equally and that in 12 85 per cent of the patients both the lower and upper extremities sustained wounds. There was very little difference in the number of wounds of the two sides except in the shoulder arm and thigh where wounds of the right side predominated (Table III).

The arm was most frequently injured 26 48 per cent of patients having been wounded in this area while the elbow was least frequently injured. The hand was involved in 19 74 per cent of patients a very high incidence considering the comparatively small surface exposed. Among the patients with injuries of their hands there were ten whose hands were badly mutilated when they attempted to return enemy grenades or to recover those fumbled by our own forces.

FRACTURE

Two hundred thirty five patients who had extremity injuries of the soft tissue had also sustained fractures. One patient had suffered a dislocation of the elbow while 2 patients sustained a fracture dislocation of the hip. The percentage of patients with compound fractures was 92. Very often multiple fractures were present in the same individual. In Table VI the various bones of the extremities are listed with the number of fractures comminuted compound or simple in type.

TABLE VI — DISTRIBUTION OF FRACTURES IN 235 PATIENTS

Location	Number fractures	Number comminuted	Number compound	Number simple
Scapula	36	18	25	1
Clavicle	7	3	7	
Head and neck of humerus	12	12	12	
Shaft of humerus	47	20	45	2
Radius	10	13	18	1
Ulna	38	24	30	8
Carpals, metacarpals, and phalanges	51	37	51	
Pelvic bones	7	4	5	2
Head and neck of femur	4	3	3	2
Shaft of femur	30	22	20	1
Lower femur	1		1	
Patella	3	3	3	
Tibia	21	13	20	1
Fibula	12	5	10	2
Tarsal bones	7	3	6	1
Metatarsals and phalanges	8	0	7	1
Totals	502	198	270	22

GENERAL TREATMENT

The arrest of hemorrhage and the treatment of shock were of course given primary consideration. Tourniquets and pressure dressings usually controlled the hemorrhage in only a few instances was it necessary to ligate a vessel in order to stop the bleeding and this was done during the treatment of shock. The combination of circumstances which necessitated operative intervention in wounds of the extremities before adequate treatment of shock presented itself rarely.

When a patient in shock was admitted to the ward morphine sulfate was given hypodermically for pain if necessary unless the patient had been given this drug previously and recently. External heat was applied and the foot of the bed elevated. Plasma was administered in sufficient quantities, as many as 8 units being given to some patients very soon after their admission. Arrangements were made for transfusion of blood.

To all of the battle casualties admitted to this ship (984) nearly 500 units of plasma were administered. We could not determine the exact number used in the treatment of patients with injuries of the extremities alone. Most of this plasma was given during the first 2 days.

Nearly all of the patients in shock had lost blood and in this type of patient there is no adequate substitute for whole blood transfusion.

TABLE VII.—AMPUTATIONS PERFORMED

Site of amputation	Number	Indications			Per cent of amputations
		Guns, gunshot	Vascular injury	Irreparable damage, crushing etc.	
Arm					22
Forearm					64
Fingers				1	44
Thigh					1.30
Leg					74
Total	14	1	2	1	100.00

sions. In many instances there was a striking difference in response to plasma and blood. One hundred fifty-seven transfusions were given all by the indirect method. There was but one serious transfusion reaction.

In summary the relief of pain, apprehension and fear, the control of hemorrhage and the restoration of body fluids by the administration of plasma and whole blood were considered prerequisite to the definitive treatment of wounds of the extremities.

TREATMENT OF WOUNDS

When indicated, roentgenologic studies were made before the patient was brought to the operating room. The surgeon was aware of the presence of metallic foreign bodies and fractures, and of nerve, tendon and vascular involvement.

The skin surrounding the wound was washed thoroughly with soap and sterile water. The wound was then irrigated with copious quantities of sterile normal saline solution. The recesses of the wound were exposed with the sterile gloved hand so that all parts of the wound could be adequately irrigated and cleansed. It was amazing how frequently dirt, grass, pieces of clothing and burnt

tissue were found in the depths of the wounds and in crevices which could be disclosed only by the fingers or an instrument. We feel that the arguments against the irrigation of wounds of the extremities have little basis in fact and we know of no other way in which a wound can be so well cleaned.

The area was then draped and preparations were made for a surgical procedure under aseptic conditions. The skin edges were trimmed and nonviable muscle and fascia were excised. Bleeding points were carefully clamped and ligated usually with fine plain catgut. The depths of the wound were then exposed and inspected again in order to be positive that no debris remained. Vaseline gauze was then placed in the wound, following which a large sterile dressing was snugly applied.

Tendon suture was found very infrequently to be indicated in these fresh war wounds. In most of the large wounds of the hand and foot, and in some of those of the forearm and leg the tendons were badly avulsed and were beyond any possibility of repair. They had to be excised often with the fingers and toes, but in routine débridement the excision of tendons was as conservative as possible. When the tendons were intact but exposed it was desirable to cover them. In a few instances this was done in our cases by a sliding skin graft. The only tendon repair in this group of patients was on a patient who had a clean wound of the leg with laceration of the tendons of the peroneus longus and the peroneus brevis. The tendons were approximated with silk and the wound was partially closed. Immobilization was maintained by plaster.

Primary suture of a war wound although it may appear clean and suitable for such treatment has been found to be hazardous and is rarely warranted under the prevailing circumstances. We have observed a few wounds that were sutured before reaching us and in a high percentage of cases they became infected and broke down.

What should be the policy in regard to the removal of metallic fragments and bullets? In many cases they are discovered and can be removed easily during the débridement. This is desirable. We feel that it is not wise to

TABLE VIII.—AMPUTATIONS PRESENT ON ADMISSION

Site	Number
Arm	
Forearm	
Fingers	5
Thigh	4
Leg	3
Toes	4
Total	30



Fig 1 Photograph of patient who was admitted soon after injury. This photograph illustrates some of the problems encountered in caring for large numbers of fresh casualties.

make an extensive search for a foreign body opening new planes and traumatizing tissues and that it is better to leave them until a later date. If a metallic body lodges just beneath the skin and is tender it becomes advantageous to remove it, and it is necessary to remove those that impinge on large vessels and nerves. In most instances the removal should be undertaken, as indicated only when the wounds have healed and the possibility of infection is remote.

Even soft tissue wounds of the extremities require immobilization. On this ship such immobilization has best been accomplished by the use of plaster splints and casts. The increase in comfort, the loss of fear and apprehension and the acceleration in rate of recuperation after immobilization have been repeatedly demonstrated.

CHEMOTHERAPY

Probably no other group of drugs has ever been received with such widespread acclaim as have the sulfonamides. Lowered morbidity and mortality in both battle casualties and accidents of civil life have been attributed to the efficacy of the sulfonamides. In recent months, however, some doubt has arisen as to

the value of these drugs in the treatment of war wounds when applied topically or when administered for their general effect or by both methods. Because of many factors it was not possible to determine with accuracy the effect of sulfonamides consequently more than a comment regarding their use may be misleading. We have observed many wounds into which has been placed sulfonamide and in some of these the powder had become caked, there was much discharge and the tissues appeared indolent. Removal of these lumps and the cleansing of the wound were followed by rapid and marked improvement. We believe very strongly that if sulfonamides are to be used for topical application the more readily soluble forms should be used and then only with great care so that the drug may be distributed evenly throughout the extent of the wound and not dumped in so as to act as a foreign body. The absence of spreading pyogenic infection and septicemia in this group of patients was noteworthy and it is possible that these results were achieved to a great extent by the use of sulfonamides. It has been our impression however that occasionally there has been so much reliance placed on the efficacy of sulfonamides that the accepted and



Fig. Roentgenogram of fractured femur which shows the external constriction so often present in the compound fractures of battle casualties.

time proven methods of surgical care have been neglected. We are inclined to attribute a large portion of the results described to the liberal use of plasma, blood transfusions, and to the treatment of the wounds by the methods outlined in this paper.

PERIPHERAL NERVE INJURIES

Injuries of the peripheral nerves occurred in 53 patients, or 8.3 per cent of the patients who were wounded in the extremities. The radial nerve was the most frequently involved of all peripheral nerves, injuries to it constituting 30 per cent of the peripheral nerve injuries, and it was traumatized nearly twice as often as the ulnar nerve (Table IV). This finding is consistent with the fact that the arm was the most common site of injury, the high incidence of fractures of the humerus, and the known vulnerability of the radial nerve.

In approximately half of the peripheral nerve injuries the loss of function and sensation was not complete. These were classified as cases of partial avulsion or contusion of the nerves. The remainder of the cases were put in the classification of complete avulsion of the nerves.

Thirty-four or 64.1 per cent, of the nerve injuries were caused by fragments while 19 or 35.9 per cent were caused by bullets. The nerve injury was associated with a fracture in 19 cases.

In no case were the circumstances suitable for primary nerve suture. Contractures prevented by the use of splints and cast

INJURIES TO LARGE VESSELS

In avulsion of an extremity and in crushing injuries there is naturally involvement of the large vessels to the part. We were surprised at the small number of patients whose wounds were primarily injuries of the large vessels, however. Undoubtedly many combatants succumb to hemorrhage before they reach a medical activity, and possibly some of the extremities which had been removed before the patients reached us (Table VIII) were amputated because of vascular injuries.

There were but 9 cases which we could classify as injuries to large blood vessels. The subclavian vein was injured once and following a secondary hemorrhage, was partially occluded by suture (Table V).

The remaining 8 patients sustained injuries to the vessels of the lower extremity, 4 to the femoral and 4 to the popliteal. In 7 of these patients gangrene occurred and amputation was inevitable. In one patient following ligation of the popliteal vein because of hemorrhage, circulation in the foot gradually improved.

Patients with injuries to the large vessels presented individual problems. In some cases the vessels were ligated immediately to control hemorrhage. In others extravasation of blood occluded the vessels and stopped the hemorrhage. It was found that after replacement of lost blood, and control of hemorrhage, amputation usually could be deferred until the formation of a line of demarcation between healthy and nonviable tissue.

We are occasionally asked if suturing of wounds of large blood vessels has been attempted. In the wounds which we have seen the vessels were damaged considerably, the wound edges were very irregular, the ends of the vessels sometimes were retracted, and the

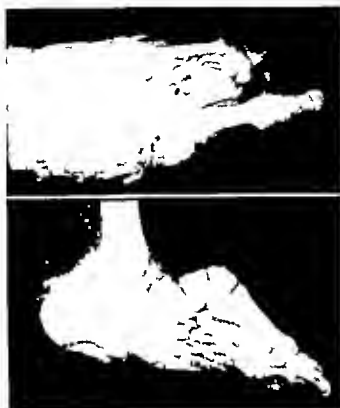


Fig. 3. Roentgenograms of badly mutilated foot which illustrates the extensive damage caused by some missiles. These cases present problems in regard to treatment.



Fig. 4. Roentgenogram of a foot which had sustained gunshot wound in tarsal region.

surrounding tissues were edematous and ecchymotic. The possibility of infection was great. In short more unfavorable conditions for the restoration of the continuity of a blood vessel are hardly imaginable.

The following case illustrates some of the problems encountered

A private first class, U.S. Marine Corps reserve aged 21 years was admitted on February 3, 1944. He had been struck in the left thigh by a bullet on the preceding day. Several hours later a corpsman reached him and administered plasma. More plasma was given at the first aid station.

Physical examination revealed a large, well developed man who was lethargic and responded poorly. Temperature was 101.4 degrees. Pulse rate was 140 per minute. Respirations were 26 per minute. There was a small wound on the lateral aspect of left upper thigh, a larger wound about 3 centimeters in diameter medial to the femoral vessels. Blood oozed from both wounds. The entire thigh was edematous, ecchymotic, and tense. The left leg and foot were mottled and cold. Pulsations could not be felt in the popliteal, dorsalis pedis nor in the posterior tibial artery. Examination by means of the x ray was negative. Erythrocytes numbered 1,770,000 per cubic millimeter of blood. Leucocytes numbered 7,850 per cubic millimeter and the hemo-

globin estimation was 6.5 grams per 100 cubic centimeters of blood.

Two liters of glucose solution and 2 units of plasma were given immediately. Sulfathiazole therapy was started by mouth and gas gangrene antitoxin was given. A firm dressing was applied to the wounds.

The general condition improved slowly and the ecchymosis which extended to above the inguinal ligament, began to recede. The lethargy decreased. The left foot and leg became cyanotic to the midleg. Three transfusions of 500 cubic centimeters each were given.

On February 11, 1944, when the patient was dismissed from our care the temperature was normal, the swelling and ecchymosis of the thigh had disappeared, the wounds were clean and were healing and there was a definite line of demarcation at the mid leg. We felt that amputation could be performed with a greater degree of safety at the conclusion of this period than at any other time.

TETANUS TOXOID AND BACILLUS ANTITOXIN

Although these patients had previously been given a booster dose of tetanus toxoid before they went in combat, it was our policy to give all wounded an additional dose when they came aboard unless one had been given elsewhere subsequent to the time of injury. No case of tetanus developed in this series indicating that toxoid is of value and produces an immunity to tetanus.

Gas bacillus antitoxin was administered as a prophylactic measure to some patients, however the greater majority did not receive any. Of 7 patients who developed gas gangrene only 1 had been given the prescribed prophylactic therapy. We are unable to draw conclusions concerning the efficacy of the serum from a prophylactic standpoint. Inasmuch as the only cases of gas gangrene that

we encountered were in patients with large deep wounds, we believe the antitoxin should be given to patients with wounds of that type.

In those patients developing gas gangrene we employed serum in adequate amounts along with various other therapeutic measures, i.e. surgery chemotherapy penicillin and transfusions. Its value as a therapeutic agent could not be determined due to these variables.

PENICILLIN

Our experience with penicillin has been limited. It was used as a therapeutic measure in all cases of gas gangrene 15,000 units of the drug being given intramuscularly as soon as the diagnosis was made. Every 3 hours thereafter a similar amount was given by the same route until the patient's temperature returned to normal. Because so many agents were used in an effort to control this infection, it would be presumptuous for us to judge the value of penicillin in the treatment of gas gangrene. At the present time it is the adjunct to surgery that holds the most promise.

GENERAL TREATMENT OF FRACTURES

When large numbers of fresh compound fractures are being received it is necessary that the most seriously injured be treated first. Those individuals in shock were given treatment immediately. They were treated by the usual measures before any care was rendered the fracture. While these patients were receiving shock treatment, those individuals with extensive injury to the soft tissue were cared for as well as those coming aboard whose trauma was of such a nature as to necessitate the application of a tourniquet elsewhere. After these had been operated upon those with less extensive soft tissue wounds were seen.

Wound treatment The care of the wounds associated with fractures was much the same as has been outlined for soft tissue injury without fractures. In addition we have removed small accessible pieces of bone or a foreign body if we believed they would interfere with reduction of the fracture. A trimming operation of the wound, thorough cleansing with soap and water (being sure that all injured tracts are washed) followed by massive saline irrigation of the wounds, have given

excellent results in our hands. In no instance have we encountered a pyogenic infection any severity as indicated by the patient's general condition and temperature. We are of the opinion, from our observations of 4 cases, that time-consuming massive excision of soft tissues is unwarranted. It is physically impossible to care for patients in this way unless we are to delay the treatment of others who are wounded. Such delay which would constitute days, might lead to well recognized complications of those wounds not treated early.

Reduction If possible, reduction of a fracture was accomplished by conservative measures. When necessary Stenmann's traction was used to overcome shortening. Pins were incorporated in a plaster cast in order to maintain satisfactory reduction. All reductions of fractures of the long bones were performed under fluoroscopic control and post reduction x ray examinations after the cast had been applied were made to check the position of the fragments.

Immobilization From our experiences with these cases plaster immobilization has been quite satisfactory and was the method of choice in treating such badly comminuted fractures as were seen in this type of warfare. After a fracture had been reduced properly and immobilized by this medium the patient was comfortable. Even though the patients were confined to bunks aboard a ship they could be turned easily. Quite frequently the cast immobilizes a wound which was large and in close proximity to a joint therefore there was less pain and less likelihood of joint contracture. Some observers believe that aboard ship fractures of the long bones should be treated by half pin devices in order that if necessary the individual may abandon ship more easily and while in the water the fractures will be immobilized. We are unable to substantiate such reasoning. We cannot subscribe to the use of these devices because in doing so we would be discarding a proved and satisfactory method of treatment of a compound fracture merely in anticipation of a situation very unlikely to arise. The placing of multiple pins in healthy bone where they will be in close proximity to large potentially

infected wounds is unsound surgery. Contamination of the pin holes might take place leading to infection of healthy bone. The bones were so extensively comminuted that it was rare to find one fractured in such a manner as to make application of one of the devices possible.

When patients were ambulatory the hanging cast was used to treat fractures of the midhumeral shaft. In a few instances we have found that correction of overriding of fragments was not accomplished because the cast would become adherent to the wound dressing thus preventing traction. In order to prevent this we suggest wrapping the dressing with a thin layer of oiled silk. This will prevent soiling of the cast by wound seepage and will avoid adherence of the dressing to the cast.

Potential gas gangrene associated with fracture. It has been our misfortune to encounter 5 cases of malignant gas gangrene which developed in compound fracture (18.5%). In all instances the fractures involved the long bones. There was extensive damage to the soft tissues and severe comminution of the fractures. Treatment of these cases was rendered in the manner outlined. We were impressed with the insidious onset of symptoms suggesting gas gangrene. We are of the opinion that an early clinical diagnosis of gas gangrene was not made due to the insidious onset of infection as well as the fact that a plaster cast prevented examination of the wound and surrounding tissue. Because of the delay in diagnosing this complication, the infection had spread necessitating high amputation of the extremity. In order to insure earlier recognition of gas gangrene, in compound fractures of long bones with extreme damage to the soft tissues, we recommend in carefully selected cases, a waiting period of 3 days between the débridement and reduction and immobilization. Such treatment should be reserved for compound fracture in which the soft tissue has been extensively macerated. During the interval the extremity can be maintained in position by a Thomas splint for the lower extremity or a Jones splint for the upper extremity. An earlier diagnosis of gas gangrene can be made leading to measures

which might save an extremity. If amputation is necessary the site of operation might be a low one affording a more satisfactory prosthesis.

AMPUTATIONS

In this series 34 amputations were performed 70.5 per cent were necessary because of irreparable damage 17.6 per cent for gas gangrene and 14.7 per cent for vascular injury. In Table VII is listed the site of amputation with the number for each part. Also is listed the indication for amputation.

In the battlefield a guillotine type of amputation may have its indications otherwise such a procedure is unjustified. If the amputation is performed at a medical unit where an anesthetic can be given and where shock can be treated preferably before the operation is done we believe a flap type of operation to be the one of choice. The additional short time required in doing this operation is not a contraindication, for the patient can receive the same shock care on the operating table as he would in bed. Skin flaps should be left open and no sutures placed in the fascia if the operator believes they should be left unsutured because of infection or potential infection of the stump. There is no logical mechanical or physiological reason to lead one to believe that two skin flaps afford an opportunity for infection to locate in the stump. After a few days if the open stump is clean a secondary suture of the fascia and skin can be done in a short period of time. It is our opinion that nothing is lost by performing amputations with flaps. The many secondary complications resulting from a guillotine operation i.e. osteomyelitis, conical stump requiring plastic procedures and reamputation would be avoided.

COMPLICATIONS

Infection. Pyogenic infection was present in the wounds of 4.3 per cent of patients as determined by inspection of the wound and the systemic signs of infection. In no case was there a spreading pyogenic infection. It would have been of academic interest to culture all wounds, but this was not practicable and would hardly have altered the treatment (Table IX).

TABLE IX.—COMPLICATIONS

	No. patients	% of (unoperated)	Died
Grossly infected wound, mild	28	25	
Secondary hemorrhage	3		
Gas gangrene	7	3	2
Thrombophlebitis			
Pulmonary embolism			
Pleurisy			
Pneumonia			

Note. Does not include concomitant conditions such as hemorrhus, peritonitis, intracranial injury, etc.

Secondary hemorrhage. In 3 patients secondary hemorrhage, one of the most dreaded of all complications, occurred. In 2 patients the hemorrhage was controlled by ligation blood and plasma were administered and the patients recovered. One patient, with a large, infected wound of the popliteal space which had been previously packed in another facility, had a secondary hemorrhage during the night which was controlled only after he had become nearly exsanguinated. After his condition improved and while preparations were being made for operation there was another massive hemorrhage. It was necessary to amputate in order to control the bleeding. The patient died suddenly of collapse.

Gas gangrene. There were 7 cases of gas gangrene an incidence of 1 per cent in 638 patients. Plasma, transfusions, penicillin, sulfonamides, multiple incisions, and amputation were employed in combating this serious infection. There were 2 deaths, a mortality of 18 per cent. In one group of patients who were wounded while in the water or immediately after going ashore, there were no cases of gas gangrene. One patient who developed gas gangrene was wounded aboard ship. 6 patients were wounded while fighting on land.

Miscellaneous. Phlebitis, pulmonary embolism, pleurisy and pneumonia were seen once each as a complication of wounds of the extremities.

Deaths. In this group of 638 patients who had been wounded in the extremities there were 8 deaths, a mortality of 1.2 per cent. In 5 cases the patients were in extremis on admission and died a short time after being brought aboard. One of these patients had gas gangrene infection of the arm which had extended to his chest wall. The 4 other patients had extensive multiple injuries, including thoracic

wounds, fractures of the skull and traumatic amputation of multiple extremities, which were complicated by profound shock.

Of the 3 remaining patients, all of whom were under our care for more than 1 day before death: 1 died of a pulmonary embolus, 1 of gas gangrene of the leg and 1 succumbed following massive secondary hemorrhages. In this series the mortality rate of patients with wounds of extremities who survived the first day aboard ship was 0.4 per cent.

Statistics in regard to the mortality of wounds of the extremities sustained in battle are not readily available. As a basis of comparison and as a commentary on the progress of surgical care it is interesting to recall that according to Boehler in World War I the average mortality rate of fractures of the femur was 50 per cent and that in the Crimean War the mortality rate of gunshot fractures of the femur was 96 per cent; the remaining 4 per cent were amputated.

SUMMARY AND CONCLUSIONS

1. Of 984 patients wounded in amphibious warfare 64.8 per cent sustained wounds of the extremities.

2. The majority of extremity wounds were caused by fragments from shells, bombs, or grenades. Wounds inflicted by thermal agents, bayonets and swords constituted a small percentage of the total.

3. Wounds of the extremity varied from minute puncture wounds to large avulsions. Seventy-two and five tenths per cent of the patients had deep wounds.

4. The lower and upper extremities were equally involved. The upper arm was the area most frequently injured. Twenty-six and forty-eight hundredths per cent of patients received wounds of this region. The hand was injured out of proportion to its size.

5. The peripheral nerves were injured in 3.3 per cent of patients with extremity wounds. The radial nerve was most frequently injured.

6. The incidence of injury to the large blood vessels was surprisingly small. Conditions favorable for suturing torn blood vessels were not encountered in this group.

7. Thirty-six per cent of patients with extremity wounds sustained fractures. Ninety

one per cent of the fractures were compound. Nearly all fractures were extensively comminuted.

8 Shock and hemorrhage were treated and controlled before definitive treatment was performed. Ten per cent of patients required immediate treatment for these conditions. Transfusion of whole blood was the most valuable measure in the treatment of shock associated with hemorrhage.

9 Conservative but thorough débridement, cleansing of the wound with sterile water and soap and adequate irrigation of all tissue planes with normal saline solutions followed by placing of vaseline gauze in the wound has proved to be a satisfactory method in caring for war wounds of the extremities.

10 Foreign bodies should not be removed in fresh casualties, except when accessible or when their presence interferes with the reduction of a fracture, or when they are pressing on large blood vessels or upon nerves.

11 The treatment outlined for soft tissue wounds has given satisfactory results when used in wounds associated with fractures.

12 Reduction of fractures should be accomplished by as conservative means as possible.

In general plating of fresh war fractures is contraindicated.

13 Plaster immobilization with incorporated pins when necessary is a satisfactory method of treating these fractures. In carefully selected cases of fractures of the long bones with extensive soft tissue injury in which muscle is macerated it is advisable to delay for 3 days cast immobilization in order that the injured part can be examined for the development of gas gangrene.

14 The guillotine operation should be reserved primarily for those cases in which speed is a prerequisite. Where the facilities of a complete hospital are afforded the flap type operations with delayed closure if necessary are recommended.

15 Pyogenic infection occurred in 4.3 per cent of patients with extremity wounds. In this series no serious infection from this cause was encountered.

16 Gas gangrene developed in 1 per cent of the patients with extremity wounds. The mortality rate from this condition was 18 per cent.

17 The mortality rate of all patients with extremity wounds who survived the first day aboard ship was 0.4 per cent.

SKIN GRAFTING AND SECONDARY CLOSURE IN WAR WOUNDS

A Preliminary Report

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THE treatment of war wounds may be divided into three periods: the early, the convalescent, and the late period. During the early period hemorrhage is controlled, foreign bodies are removed, and débridement is accomplished. The excellent condition of the majority of the battle wounds coming to us is proof that this phase of treatment is being well performed. The convalescent period concerns itself with closure of the wound and restoration of function. The late period is limited to certain wounds which months or years later require reconstructive procedures to improve function or to correct cosmetic defects. It is the second, the convalescent period, with which this study is concerned.

Adequate treatment of war wounds during the convalescent period offers many problems. If they are allowed to close spontaneously, not only is much time consumed but deforming scars may result.

From July 12 to October 31, 1943, inclusive, of patients admitted to the surgical service, 967 were battle casualties. During this period, 145 plastic procedures were performed, practically all of which were on wounds of the extremities. Of these procedures, 81, or 56 per cent, were secondary closures and 64, or 44 per cent, were skin grafts. Relatively few of these operations were done during July and August as the hospital during the Sicilian campaign was serving as an evacuation hospital. During the first week of the Italian campaign, we were authorized to make a study of the efficacy of early skin grafting and secondary closure of wounds. Consequently, 140 of the 145 procedures were performed during September and October.

Shortly after the beginning of this study, a mimeographed form was utilized for keeping

TABLE 1.—PLASTIC PROCEDURES, JULY 12 TO OCTOBER 31, 1943, INCLUSIVE

	Secondary closures	Skin grafts			Monthly totals
		Split-thickness	Full-thickness	Reversal	
July					
August					
September	5	6			11
October		43			43
Total	5	49			54

detailed record of each case. Such a record has been completed on 97 patients, representing 114 plastic procedures on a total of 144 wounds. It is upon this latter group that this report is based.

GENERAL CONSIDERATIONS

Most of these cases were battle casualties; only 5 were not traumatic in origin. Forty-eight patients were injured by shell fragments, 15 by bullets, 2 by mine explosions, 1 by grenade and 11 were injured in accidents. The type of missile was not stated in 11 cases. One hundred and twenty-five of the 144 wounds, which are being reported in detail, were wounds of the extremities. The others were gluteal, 11; chest wall, 3; genital, 2; abdomen, back, and perineum, 1 each. Eighteen or 13 per cent of the wounds treated were associated with compound fractures. This number does not include phalangeal fractures.

Previous treatment. Débridement had been done in 63 cases before arrival at this hospital; in 16 cases dressings only had been done; 16 had had amputations. Only 1 patient in this series entered with a fresh wound.

Time interval. In the 97 cases, an average of 4.9 days had elapsed between injury and admission to this hospital. An average of 19.5

days elapsed between injury and plastic operation

Treatment of the wound The wound was inspected upon arrival at the hospital. If necessary a toilet of the wound was done which consisted of the removal of all necrotic elements. Continuous aqueous azochloramid was started and continued until the wound appeared sufficiently clean. For at least 48 hours before the skin graft or secondary closure continuous dressings of hot boric acid solution or normal saline were used. The wound overlying a compound fracture was treated in much the same way through a window in the cast. Bacteriological studies were not done as it is well known that all of these wounds are contaminated. The plastic procedures were done when the wounds appeared to be surgically clean.

Size of wounds To determine accurately the size of the wounds metal rulers were incorporated in the operating setup. It is surprising how much one can err in estimating the size of a wound. The largest area grafted was a third degree burn comprising slightly more than 90 per cent of a lower extremity. The smallest was a 1 by 1 centimeter wound of the wrist on which a split thickness graft was placed.

Special considerations Foreign bodies were present in the immediate vicinity of wounds in 9 instances. The bone was exposed in 14 wounds and tendon was exposed in 7.

Type of operation Fifty six or 49 per cent of these 114 operations were secondary closures. 54 or 47 per cent were skin grafts and 4 or 4 per cent were combinations of the 2 procedures.

Anesthesia Local anesthesia was used more often than any other having been employed 53 times. Spinal anesthesia was used for 34 procedures pentothal for 15 and ether for 12. In general local is the anesthetic of choice in the treatment of smaller wounds. The graft is taken after intracutaneous infiltration the orange-peel effect from the distention of the skin making it relatively easy to cut the graft. We feel that a razor blade held in a straight clamp is the best instrument for taking the smaller grafts. The thigh need not be the donor site as any convenient area of skin on the extremity or the trunk may be utilized.

Sulfanilamide No delay has been noted in the healing of wounds nor has there been any interference with take of the graft in those cases in which sulfanilamide crystals were used locally. We feel that it should be employed routinely.

Immobilization No form of immobilization was deemed necessary in 61 instances. Plaster of-Paris was used 35 times splint 9 times sling 5 times ace bandage 3 times and adhesive strapping once. Molded plaster is a most convenient agent for immobilization in plastic procedures on the extremities. Grafts and closures were frequently done through a window in the cast if removal of the existing cast was deemed inadvisable. For shoulder and arm wounds a double sling is most effective.

SKIN GRAFTING OF WOUNDS

Excision of margins The margins of recipient areas were usually not excised prior to grafting. Exceptions were made in indolent wounds with unhealthy edges.

Donor site The anterior surface of the thigh was used most frequently as the donor site. The posterior surface was used when the wound to be grafted was located on the posterior aspect of the lower extremity. When very large grafts were necessary the abdomen, chest or back were utilized.

Drainage Wounds with draining pockets or sinuses received special attention. The pocket or sinus was drained either through a rent in the graft or to the side of the graft. One of the authors preferred wet dressings to the vaseline dressings. The dressings were kept continuously moistened by aqueous azochloramid or boric acid solution injected through a Dakin's tube incorporated in the dressing. These grafts were generally dressed and the drain removed in 2 to 4 days. The moist dressings were continued for 7 to 10 days after operation. The aqueous azochloramid did not seem to injure the grafts. In an occasional case blistering of the normal skin was encountered. The end results were the same whether the moist or the routine vaseline gauze dressings were employed.

Wounds were not drained simply because of irregularities on the surface of the recipient area. In these vaseline gauze was molded into

the depressions, over which stuffed gauze was placed to aid in maintaining even pressure throughout the grafted area.

Drainage was instituted in the grafted cases 12 times, and no drainage was used in 45 wounds. None of the four wounds treated by the combination of graft and closure was drained.

Suturing of grafts The grafts were most often sutured in place first by anchor sutures of No. 0000 Deknatel silk followed by continuous suture around the graft. Some thin split thickness grafts may do well without suturing.

Pressure The necessity for even pressure over the grafted area cannot be overstressed. Mechanics waste is an excellent substitute for sea sponge if care is exercised to stuff it well to remove its lumpiness. It is advisable in extremity dressings to apply a wad of waste on the side of the limb opposite the dressing to produce an equalized pressure on the limb thereby avoiding undue pressure on vessels and nerves. The pulse should be checked distally after the application of a snug bandage to the extremity.

Instrument The Padgett dermatome was employed 25 times, the Ferris Smith skin graft knife and the razor blade were used 15 and 9 times, respectively. The dermatome was used in all instances in which large defects were covered. The razor blade is excellent for cutting a strip to fill the granulating area of a long narrow wound.

Complications There was infection of the recipient area in 3 cases and in 2 there were mild infections of the donor site. Scarlet fever occurred in 1 of our grafted patients and the graft failed to take.

Postoperative dressings With the exception of those cases in which drainage had been instituted in the recipient area, these wounds were not dressed sooner than 7 days following operation as a rule. In very large areas or in grafts of amputation stumps the wound was not disturbed for 2 weeks or longer.

The further we went in this work, the less we tended to be discouraged by the appearance of some of the grafts at the end of a week or 10 days. Some areas, which at that time seemed to have relatively little take, were

completely healed in 21 days. The explanation obviously is that certain areas which appear to be unsuccessful are in reality covered with very thin epithelial layer.

Results in skin grafts We have arbitrarily chosen 21 days as the time at which an estimate should be made of the extent of the take of the graft or the percentage of healing in wounds secondarily closed. Any area that has not healed by that time was considered a failure.

TABLE II.—PERCENTAGES OF TAKE OF SKIN GRAFTS (79 wounds)

	Cases	Per cent
75 to 100 per cent	5	63
50 to 75 per cent		6
25 to 50 per cent		3
0 to 25 per cent		3

SECONDARY CLOSURE OF WOUNDS

The nature of the wound is the most important factor in deciding whether a skin graft or a secondary closure should be performed. Lacerated wounds in which the edges are not too far apart or penetrating wounds in which there has not been appreciable loss of tissue do well with secondary closure. Wounds in which there is considerable separation of the skin and wounds in which the granulation tissue lies at or near the surface of the skin are more amenable to skin grafting. Small lacerated wounds often heal promptly by the use of an adhesive approximation.

Fifty-six, or 49 per cent, of the 114 plastic procedures were secondary closures.

Prior to secondary closure the same preoperative management of the wound was followed as in the skin graft cases. The edges of the skin were in most instances trimmed and a slight toilet of the wound was done if indicated. The choice of suture material did not seem to make a great deal of difference provided undue tension was avoided. Equally good results were obtained with wire, silk and silkworm gut.

Immobilization is as important after secondary closure as it is after skin grafting. Drainage was instituted in secondarily closed wounds if dead space remained beneath the coapted margins. Twenty-five or 42 per cent secondary closure wounds were drained and

34 or 58 per cent, were closed without drainage. Infection occurred postoperatively in only 3 wounds.

TABLE III.—PERCENTAGES OF HEALING IN SECONDARY CLOSURES (77 wounds)

	Cases	Per cent
75 to 100 per cent	55	71
50 to 75 per cent	8	10
25 to 50 per cent	2	3
0 to 25 per cent	12	16

The apparent discrepancy in the number of wounds is attributable to reoperation in a small group.

The results in the 4 wounds in which a combination of skin grafting and secondary closure was used are 3 wounds 75 to 100 per cent, 1 wound 50 to 75 per cent.

PLASTIC PROCEDURES ON WOUNDS ASSOCIATED WITH COMPOUND FRACTURES

Skin grafts. Eleven split thickness skin grafts were placed on wounds associated with compound fractures. Phalangeal fractures are not included. The compound fractures were located as follows: metacarpals 3, tibia 2, fibula 2, radius 1, ulna 1, femur (internal condyle) 1, and metatarsals 1. These wounds averaged 9 centimeters by 5.5 centimeters. The largest wound was 15 centimeters by 11 centimeters associated with a compound fracture of the tibia in which there was considerable loss of bony substance. Bone was exposed in 6 of the cases. In these cases the grafts took over bone where the periosteum was intact. Bony spicules protruding through the graft were removed with the rongeur. If a draining sinus was present a rent was made in the graft and a rubber tissue drain was inserted through it into the sinus. The average take of these grafts was 78 per cent.

Secondary closures. Secondary closure has been performed on 7 wounds over compound fractures. The fractures involved the following bones: scapula 2, femur (greater trochanter) 2, fibula 2, and metatarsals 1. These wounds averaged 8.6 centimeters by 4 centimeters, the largest being 16 centimeters by 8 centimeters. Rubber tissue was used where drainage was indicated. The average healing of these wounds at 21 days was 80 per cent.

OBSERVATIONS

A comparison can hardly be made of the results of skin grafting and secondary closure since in most instances these procedures are used in different types of wounds. As this study progressed we tended to treat more wounds by skin grafting than by secondary closure. Covering large granulating wounds with skin dressings offers definite advantages. By sealing the wound the element of infection is eliminated and the tissues are allowed to return more promptly to a normal state.

These plastic procedures seem to promise a shortened period of disability for patients with compound fractures. Skin coverings over their wounds keep out infecting organisms which would continue to gain access through an open wound. In cases in which indicated reconstruction operations may be done at an earlier date. Plastic procedures on these wounds do not increase the period of hospitalization because these patients are already under prolonged treatment for their fractures.

In dealing with war wounds, especially the larger ones, one cannot strive for the ultimate in cosmetic result.

Reverdin grafts, although not advisable as routine procedure, should not be totally discarded. They have, we believe, their particular place in bridging over those last few millimeters of wound. It is suggested that these grafts be taken from the immediate vicinity of the wound where the tissues are already more or less disfigured.

Certain parts of the body have been found to be resistant to plastic procedures. The most recalcitrant area has been that overlying the tibia. Also one is apt to have difficulty with wounds of the sole of the foot, the buttocks, and the shoulders.

Plastic procedures in our experience have failed more often in small circular wounds than in larger ones. We could not attribute this to the presence of foreign bodies or any other factor. The reason for the poorer results in the small wounds is not clear.

Occasional patients are encountered in whom for some unknown reason both skin grafting and secondary closure are repeatedly unsuccessful.

Thin split thickness grafts seem to be surer of take than thicker ones. If there is reasonable doubt of a successful take in a given wound it is well to apply a thin graft. Thicker grafts should be placed over pressure points. Full thickness grafts were successful in the palm of the hand.

CONCLUSION

We are of the opinion that skin grafting and secondary closure are eminently worth while

in the treatment of war wounds. The period of hospitalization is definitely shortened. Many patients, who otherwise would be lost through evacuation, will be returned to duty. Patients with severe wounds of the soft tissues and those with compound fractures are rendered more comfortable. By these plastic procedures the underlying tissues are sooner restored to normal and patients are earlier prepared for any reconstructive procedures that may be necessary in the Zone of the Interior.

THE EFFECTS OF ORCHIECTOMY ON PRIMARY AND METASTATIC CARCINOMA OF THE BREAST

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FOR over two score years there has been an increasing interest in the effects of oophorectomy on mammary carcinoma both primary and metastatic. For more than half of that period the medical literature on radiation therapy has seen a substantial increase in the bibliography on radiation castration for metastatic breast cancer more especially as regards the effects of such a procedure on the secondary deposits in bone. The encouraging regressions of the skeletal metastases from mammary carcinoma following castration in women still menstruating have suggested the possibility that orchietomy might retard or even cause regression of mammary cancer in the male—both in the primary and metastatic lesions. The latter experiment was begun more than 2 years ago at the Memorial Hospital and was noted in a preliminary report 4 months after the first patient was orchietomized. Because of that result other cases for such therapy by surgery have been collected.

In 1942 Farrow and Woodard (10) were led to observe the effects of the administration of androgens and estrogens on the serum calcium in patients with skeletal metastases from breast cancer. Impressed by the favorable results obtained in the retardation of the growth of osseous metastases in mammary carcinoma by radiation castration they studied the effects of chemical castration by the injection of testosterone propionate. They found that the 3 patients who received such therapy had developed increased blood calcium levels as well as an increased output of calcium in the urine. The chemical changes were accompanied by clinical and roentgenographic evidence of increased activity in the metastatic disease in bone. The administration of estrogens was found to produce a similar effect.

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They inferred therefore that the ability of the male and female sex hormones to cause hypercalcemia in such cases was due to the stimulation by the hormones of the growth of the metastatic tumor. However this finding is at variance with the observations of Dohrner and of Abels (11) who administered to each of 2 patients a total of 3 grams of both crystalline testosterone and testosterone propionate without producing a stimulating effect on the primary or metastatic disease or increasing significantly the calcium level of the blood.

The observations that the use of androgens and estrogens in women with breast carcinoma was deleterious, the numerous favorable results in inoperable and metastatic carcinoma produced by x ray castration and the older reports on surgical castration for inoperable breast cancer suggested that castration be tried in males. Farrow and Adair (9) observed the results of orchietomy on osseous metastases from breast carcinoma. Their patient has been reported previously but only 4 months after operation and is the first of the 6 subjects in the present communication. Enough time has now elapsed to evaluate fully the overall effects of orchietomy. At the time orchietomy was performed the clinical classification of the 6 cases under report was primary operable 1 prophylactic 1 recurrent inoperable 1 primary inoperable 3.

The consent for orchietomy even in the elderly male with advanced breast cancer was the most difficult to obtain. It appears to be a triumph of medical persuasion to obtain permission for this operation. Even an elderly male with the intense pain from osseous metastases was unwilling to undergo castration. The female who in her psychological make up expects the climacteric at one time or another is more easily persuaded to submit to oophorectomy than is the male who rarely if ever expects a complete cessation of his

sexual functions. It seems to be more difficult to obtain permission for castration in males suffering from mammary cancer than in malignant disease of the prostate

CASE REPORTS

The following case reports have been fully abstracted and have been chronologically listed in the order of the dates of their castrations.

CASE 1. M. S., a white male, aged 72 years, was admitted to the Breast Clinic of Memorial Hospital on April 8, 94. He was an Italian Catholic, married, and the father of two children. He had a mass in his left breast which had ulcerated 4 months prior to the date of his application for treatment.

On physical examination the patient in fair general condition did not appear to be 72 years of age. His full head of brown hair was only slightly streaked with gray. A loughing laceration destroyed the left nipple and areola. The edges of the lesion were rigid and umbilicated. The crater measured 3 centimeters and was partly filled with moist, grayish slough. Underlying the ulcer was a stony hard mass 5 by 6 by 2 centimeters. The tumor was movable over the chest wall. The axilla contained several firm, metastatic nodes. The genitalia were normal. Biopsy of the tumor was not obtained at the time. The x-ray examination of the lungs and thoracic cage was negative for metastases.

It was most difficult to obtain the patient's cooperation in initiating treatment and he ignored all requests for his return to clinic until 6 months following his initial examination (February 94).

Re-examination on February 5, 1945, revealed an extension of the primary lesion (Fig. 1). It was still movable over the chest wall. The nodes in the axilla had increased slightly in size and one small node could be palpated in the left supraclavicular fossa as well as the right cervical region. In addition to the original symptoms he now complained of pains in the chest and dorsal spine.

X-ray examination was made February 6, 94, of both shoulder girdles, skull, lower ribs, lumbar spine and pelvis. There are many areas of osteolytic bone destruction involving particularly ribs (Fig. 3), 4th lumbar vertebra, numerous areas in the pelvis and upper femora (Fig. 4). Two osteolytic areas were seen in the skull and one in the upper portion of the left humerus. Both scapulae were involved. Conclusions: Carcinoma metastases to bone widespread osteolytic type.

Because of the extension of the disease and the positive evidence of osseous metastases the patient's clinical classification was changed to primary inoperable and he was admitted for orchiectomy.

At operation a formal incisional biopsy specimen of the breast lesion was taken and bilateral orchi-

ectomy was done February 9, 94. The testes were removed in the routine fashion under infiltrant anesthesia with 1 per cent novocain. A wedge biopsy specimen was removed from the primary breast lesion. The patient was discharged from the hospital on the 10th postoperative day.

Pathological report: The testes showed atrophy and interstitial cell hyperplasia. The report on the biopsy tissue from the breast tumor was: Infiltrating mammary carcinoma grade II.

The patient was observed 2 weeks after the operation. He reported marked relief from the pain in the skull, ribs and spine. Slight regression was noted in the size of the mammary lesion but the red color in the surrounding skin had definitely faded. One month later regression was noted in the axillary disease. Three months later relief from the pain had become marked and the lesion appeared drier and smaller (5 by 3 by 1.5 cm.). He complained of hot flashes and profuse sweating. Clinical observation, almost continuous, for 28 months after orchiectomy showed continued regression in the primary lesion which had been replaced by a cicatrix. The last x-ray examination showed some questionable areas of reactivation of the metastatic disease in bone. This finding may be significant since the alkaline phosphatase, which had been normal since the initial rise which usually occurs immediately after orchiectomy now showed a slight elevation (from 3.8 to 5.5 units).

Reports on subsequent x-ray examinations March 3, 94: Carcinoma metastases to bone widespread, showing further advance in the skull and no evidence of calcification.

May 8, 94: Films of this day when compared with the previous views, do not reveal any well marked changes. However some of the pathological fractures in the ribs have become united with considerable callus production. The number and extent of the areas of bone destruction or metastases apparently has not increased and it appears that the progress of the disease has at least been arrested.

June 8, 94: The changes previously described are again seen. Continued slight improvement has occurred in all of these areas of bone destruction previously noted. This improvement is characterized by further calcification in the previously osteolytic sites. There does, however, appear to be a slightly greater pleural thickening. The left base than before and now an ill defined nodular densification is present in the left intraclavicular region that may represent early cancer metastases to the parenchyma. Conclusions: carcinoma metastases to bone widespread showing continued reparative changes as described previously.

May 5, 1944, examination of the cervical spine anteroposterior and lateral views showed the spinous process of the second cervical vertebra to have a large cystic area involving the posterior aspect. The remainder of the vertebrae showed decalcification but no definite evidence of a destructive process. This change noted in former examinations ap-

parently is not progressing. The areas of decalcification previously described in the skull films in the frontal and occipital regions are unchanged. The pelvis and upper femora likewise show no interval change. There is some destruction of the 12th dorsal vertebra with compression and some osteogenic reaction in this vertebra and possibly the 11th. The lumbar spine while showing generalized decalcification shows no definite destructive process.

This case represents a satisfactory and dramatic regression of a primary carcinoma of the male breast which had metastasized to bone. The breast cancer was replaced by a cicatrix (Fig 2) the metastatic nodes regressed. The secondary deposits as demonstrated in repeated x ray films showed reparative change. The repair in the ribs (Fig 5) shoulder girdle and spine were striking (Fig 6). Whether the repair process was one in which new bone replaced metastatic deposits it is impossible to say—only a formal biopsy would settle this question. The changes in the skull while showing early regression now show a diffuse haziness. One cannot say whether this is a sign of activity or bone change due to a deranged metabolism produced by orchectomy. One reason for looking upon the recent skull changes as possible renewed activity of the metastatic process is the corresponding slight but definite rise in alkaline phosphatase.

CASE 2 J S a retired sea captain of Protestant English ancestry, was 75 years of age when first examined in the breast clinic at Memorial Hospital on June 10 1941. He was married and had reared 6 children. A painless lump had been noted in the right breast 1 year prior to admission.

Physical examination revealed a well preserved white male. The examination was negative except for the breast tumor and an enlarged liver. The ulcerating carcinoma which measured 6 by 4 centimeters. It was movable over the chest wall but there was a suggestion of beginning fixation. The corresponding axilla contained metastatic nodes. The external genitalia were apparently normal. The case was classified primary operable.

X ray examination of the chest June 13 1941 was essentially negative.

Medical consultation. The enlarged liver was probably due to cirrhosis. There was a history of considerable ingestion of alcohol for 40 years. The laboratory findings however were only slightly abnormal as evidenced by (1) an abnormal bilirubin 1.2 milligrams (2) a low prothrombin level of 81 per cent (3) mild macrocytosis.

At operation July 7 1941 a right radical mastectomy was done. The patient was discharged from the hospital on the 11th postoperative day.

Pathological report. Infiltrating duct carcinoma grade III. Multiple node metastases.

The patient received a routine postoperative x ray cycle (2000 r to an anterior and posterior axillary port and 1750 r through the axilla direct). Seven months after the radical mastectomy a nodule was noted in the skin over the left occiput and an x ray film showed metastatic disease in the skull (February 26 1942). Orchietomy was advised and refused. Chemical studies of the blood showed no significant change. The patient continued free of distressing symptoms for 4 months refusing orchietomy for this reason. He agreed to receive treatment with estrogens and entered the hospital for this therapy. Between July 23 and August 18 1942 he received 19 doses of 12 000 units of progynon (228 000 R.U). Following the administration he showed clinical and chemical evidence of hypercalcemia. The lesion in the scalp increased in size, the patient complained of skeletal pain, the breast tissue in the opposite side became tender and thickened. Cutaneous nodules appeared on the forehead. Later he complained of nausea which may have been due to the cirrhosis of the liver but may have been produced by an altered calcium metabolism. In December 1942 dyspnea was evident and a thoracentesis removed 600 cubic centimeters of light straw colored fluid. In January 1943 when the patient's symptoms were numerous and discomforting he consented to bilateral orchietomy. For the purpose of this report he was reclassified as recurrent inoperable carcinoma.

Examination on readmission showed the patient's general condition to be poor. There were multiple nodules in the scalp evidence of progression in the diffuse skeletal metastases and a right hydrothorax.

At operation on January 1 1943, bilateral orchietomy under infiltration anesthesia of 1 per cent novocain was carried out.

The patient expired suddenly early on the 3d post operative day. Permission for examination after death could not be obtained.

This patient was an elderly male in fair general condition but with probable hepatic cirrhosis. His breast lesion while advanced was considered operable in spite of the ulceration. Seven months after operation a nodule was noted in the scalp over the left occiput. X ray films showed associated destructive areas in the skull. The alkaline phosphatase was elevated from 5.4 to 9.9 units. His death while not directly due to the operation was probably hastened by his poor physical condition due to the associated disease.

CASE 3 B D a 63 year old butcher married the father of one child and a Jew of Aryan descent had his initial examination in the breast clinic at the

Memorial Hospital on April 13, 1942. Fifteen years prior to his admission painless mass was excised with the right breast. Six months later four radium treatments were given over the operative site. Until December 1941 he remained free of disease. At that time swelling was noted in the right axilla. On February 5, 1942 the right axilla was dissected. He was referred to the Memorial Hospital for further therapy.

Physical examination revealed rather obese, full chested white male in apparent good health, with a well healed, old transverse scar over the right chest wall, 8 centimeters in length. A recent granulating scar extended vertically from the pole of the axilla to the previous incision. There was the usual post-operative reaction in fat but there was no evidence of disease. The heart and lungs were essentially normal. There were spinal deformities but slight tenderness could be elicited on pressure over the 8th dorsal vertebra. The genitals appeared normal.

Pathological report: While the report of the submitted slide from the axillary dissection, as given as Alveolar carcinoma, has distinguishing features indicative of origin. A further report from the axillary dissection gave the following information: Infiltrating duct carcinoma, grade II. This does not look like node metastasis, more like a second axillary primary (assuming that this tissue is from the second operation).

The films made at the time of his admission to the clinic were reported as follows:

May 7, 1942: Views of the spine show some irregularity in the density of the body of the 11th dorsal vertebra and 3rd and 4th lumbar vertebra and of the 1st dorsal vertebra, also with some irregular destruction in the proximal end of the first rib on the right side and the transverse process of 11th vertebra. Changes noted probably represent carcinoma metastases.

However, because of persistent pain roentgen studies were made and reported on as follows:

August 28, 1942: Dorsal lumbar spine and pelvis further examination. There has been practically no change in the appearance of the previously described metastases, except that there may be slight further compression of the 11th dorsal, and the 1st lumbar also appears to be involved (Fig. 7). The 3rd and 4th lumbar vertebrae are well demonstrated on the present films. No other areas of metastases are seen. Conclusions: Carcinoma metastases to bone, showing slight increase in the intensity, as described here.

The alkaline phosphatase in August 1942 was 4.8 units. While castration had been advised in June 1942 it was not until April, 1943 that he would submit to the operation. At that time the pain in his back was so intense that he sought relief. The alkaline phosphatase had risen to 6.6 units.

At operation, May 8, 1943 a bilateral orchiectomy was done under pentothal and local infiltration with 1 per cent novocain. The patient was discharged from the hospital on the 6th postoperative day.

Pathological examination of the gonads showed mild atrophy.

The patient had prompt and almost complete relief from pain. The alkaline phosphatase 3 months later was 3.7 units and 3 months ago (February, 1944) was 2.6 units. At that time x-ray views of the spine when compared with previous views reveal evidence of some bone regeneration.

This case represents a very satisfactory clinical result. The patient has been relieved of his pain and has maintained his good physical condition. The phosphatase level has returned to normal and the x-ray studies show evidence of bone regeneration (Fig. 8).

CASE 4. A. I., an Irish Catholic, 64 years of age, applied on June 1, 1943 to the tumor clinic of the Meadowbrook Hospital for the treatment of a breast tumor. He was the father of one child. The patient's past history was negative except for the presence of a bilateral hydrocele of 3 years' duration.

Physical examination revealed well developed and well preserved white male with a firm mass in the lower outer quadrant of the left breast about 3 centimeters in diameter. There were no skin nor nipple changes. The axilla contained no palpable nodes. The genitalia seemed normal except for the slight atrophy usually found in a male of this age and for the presence of bilateral hydroceles each about 3 centimeters in diameter.

Operation was performed June 2, 1943 under general anesthesia (gas-oxygen and ether) and the tumor in the left breast was excised. It was not examined in the operating room. The hydroceles were repaired by excision, the procedure being simplified by doing bilateral orchiectomy. Convalescence was uneventful, the patient leaving the hospital on the 6th postoperative day.

Pathological examination: Adenocarcinoma of the breast, bilateral hydroceles, normal testes.

The patient was examined 10 days after operation. The incision in the breast was well healed. The scrotal scars were slightly indurated. It was decided that in view of the problem in hand it would be well to rest on the excision of the breast cancer to see if orchiectomy would prevent recurrence or metastasis. For this reason the patient was examined at monthly intervals. In October 1943, a node was noted in the right axilla (opposite side) and in December this finding was bilateral. A film of the chest revealed no areas of pulmonary or osseous metastasis. The node in the right axilla disappeared but the one on the affected side remained and increased in size. On April 25, 1944, left radical axillary dissection was done under general anesthesia. The node was a hyperplastic crescent of lymphoid tissue surrounding a lobule of fat. There was no evidence of metastatic disease in the axilla.

This patient has remained free of local or distant disease following the local excision of a



Fig. 1. Case . Condition of the primary lesion in the left breast at the time of formal biopsy and orchiectomy. This is an extensive ulcerating lesion with associated involvement of axillary nodes.



Fig. 2. Case . Condition of the primary tumor 27 months after operation. The ulceration at this time has completely healed and the lesion has been replaced by a cicatrix.

carcinoma of the left breast. The only adjuvant therapy was the orchiectomy which at the time had not been planned as a therapeutic measure but for the relief of a bilateral hydrocele. The result is most satisfactory 1 year after treatment.

CASE 5. E. S., a 39 year old male of Irish Catholic ancestry, appeared in the breast clinic of Memorial Hospital on October 15, 1943. He stated that he was the father of two children. His past medical and surgical histories were essentially negative. The breast history began 6 months prior to admission when he noted a painless lump in the lateral middle portion of his right breast. Four months later nipple retraction was evident and 1 month prior to his application for treatment severe pain was complained of in the lumbar spine, of such severity that he could not bend nor lift heavy objects. He had received medication for this "rheumatism." There had been a loss of 8 pounds in weight during the 6 month interval.

Physical examination. The patient was well developed but slightly undernourished. The examina-

tion was without remarkable findings except for the breast condition. There was a deformity of the right breast with retraction of the nipple and dimpling of the skin lateral to the areola. There was an underlying tumor measuring 3 by 1.5 centimeters with a zone of surrounding reaction in fat. The tumor was slightly adherent to the chest wall. There were several definitely metastatic nodes in the right axilla but several smaller discrete ones could be palpated in the opposite side. The genitals were normal. Because of the roentgenographic findings the case was classified primary inoperable.

At x-ray examination October 15, 1943, views of the chest showed no evidence of metastasis to the lungs. The film of the pelvis showed numerous small areas of increased bone density. There was suggestive evidence of the presence of several small areas of destruction in the ribs. Film of the pelvis revealed evidence of extensive metastases.

Aspiration biopsy tissue from the primary breast tumor was reported to contain carcinoma.

At the time of admission blood was obtained for chemical analysis. The alkaline phosphatase was 7.8 units and the calcium and phosphorus levels were slightly but not significantly elevated. Castration



Fig. 3. Case . Multiple pathological fractures of the ribs of the right side.

was advised and the patient acquiesced. He was admitted to the hospital for metabolic study prior to operation.

At operation December 8, 1953, bilateral ribectomy was done under spinal anesthesia with novocain.

Pathological examination revealed. Essentially normal testicles.



Fig. 5. Case . The fractures in the ribs show definite repair with callus formation and bone replacement.

The patient remained in the hospital for 3 weeks after operation. This was essential for certain metabolic studies. His convalescence was not satisfactory for he did not show any relief from the bone pain which Patients 1 and 3 obtained. He did not put on weight. Apparently cheerful at times, he was depressed on other days. While there was a slight initial drop in the alkaline phosphatase, it never became normal.



Fig. 4. Case . Osteolytic metastases to the left side of the 4th lumbar vertebra. Numerous diffuse areas in the pelvis.



Fig. 6. Case . Repair in 4th lumbar vertebra, strikingly represented. In questionable areas of bone change peristalsis in pelvis these have not progressed since orchiectomy.



Fig. 7 left Case 3. Definite metastasis is shown in the body of the 12th dorsal vertebra.



Fig. 8. Case 3. There is evidence of bone regeneration

in the body of the 12th dorsal vertebra. Similar change is noted in the 1st lumbar. Films were made 8 months after orchiectomy.

There was no evidence of repair in the destructive areas of bone. One month after operation the phosphatase was 19.8 units and 1 month before death it had risen to 38.8 units. Death occurred April 4, 1944, 4 months following orchiectomy.

Castration in no way altered the clinical course in this 39 year old male. His pain was not relieved. The total duration of life from the onset of symptoms to death was about 12 months. The failure in this case to respond favorably following orchiectomy may have been due to the patient's comparatively young age.

CASE 6. A P. was by descent a German Catholic, aged 63, married and the father of two children. His surgical and medical histories were noncontributory. In May 1943 he noted a painless lump in his left breast and since it caused him no trouble he did not seek any relief for the condition until he was admitted for treatment on December 1, 1943.

Physical examination revealed a well developed, well nourished and apparently healthy male. Aside from the local mammary condition the positive findings were a sebaceous cyst on the right cheek and an irreducible umbilical hernia of moderate size, present for 4 years. The genitals were normal.

Examination of the left breast showed the left nipple and areola partly ulcerated and retracted. The surrounding skin was slightly bluish. Beneath this area was a partially fixed firm mass 5 by 4 centimeters in diameter (Fig. 9). In the nearby skin several ecchymotic areas were present as well as a few discrete cutaneous nodules above the tumor and near the costal margin. The left axilla contained a mass of matted metastatic nodes as large as the primary tumor.

Aspiration biopsy tissue December 1, 1943, report: Carcinoma.

X-ray examination was made December 1, 1943. Film of the chest revealed evidence of metastases to the lungs most marked on the right (Fig. 10). Views of the lumbar spine and pelvis showed no evidence of bone destruction.

The patient was admitted to the hospital for study after castration was advised. An investigation of certain phases of metabolism was undertaken before the operative procedure. While the blood calcium was at a high normal level the alkaline phosphatase was not appreciably increased.

At operation on January 9, 1944, bilateral orchiectomy was carried out under spinal anesthesia with novocain. The patient left the hospital on the 20th postoperative day. Convalescence was uneventful.

The pathological report was as follows: Testes show slight to moderate tubular atrophy. Spermato-



Fig. 9. Case 5. The primary lesion in the left breast has destroyed the nipple and a good portion of the areola. The diffuse nodular metastases in the skin are indicated. Swelling in the axilla is due to the metastatic axillary nodes.

granulosis is present. Interstitial cells are within normal limits.

There was an initial increase in the size of the breast lesion. Now the ulceration has healed over and the mass has decreased in size (Fig. 9). The axillary nodes do not seem to be altered in size or consistency. Recently slight edema of the left arm has been noted.

Following castration x-ray studies on March 9, 1944 were reported as follows: Film of the chest made today, when compared with the previous view reveals evidence of a decrease in the extent of the metastases in the lungs.

A review of these films showed an area of decalcification in the crest of the right ilium—this finding has been persistent since admission.

On April 7, 1944 the following x-ray findings were noted:

Chest—The areas of infiltration noted previously in the right lung field are less distinctly seen at this time (Fig. 10). The lower lung field shows some peribronchial fibrosis. The left lung field is unremarkable except for two small areas, one in the 6th and one in the 8th interspace posteriorly suggestive of metastatic disease. These were indistinctly seen on the previous film.



Fig. 10. Case 6. Pulmonary metastases are most marked on the right.

On May 7, 1944, stereoscopic pelvic and detailed views of the right ilium—in the region of the crest of the ilium there are irregular areas of decalcification, definitely suggestive of metastasis.

The study of the blood chemistry showed alteration.

In this patient as in the first patient, after four to five months, there has been an arrest in the growth of the primary lesion with some regression in the tumor healing in the skin and disappearance of the cutaneous metastases. The axillary nodes have apparently not regressed. There has been noticeable diminution in the size and extent of the pulmonary metastases. Early metastases to the right ilium have not extended since castration. He maintains his weight and is in an excellent state of health and nutrition. Aside from slight pain in the left arm due to edema, he is comfortable.

THE CLINICAL RESULTS OF BILATERAL ORCHIECTOMY

The following summary has been based on an analysis of the 6 patients who had bilateral orchietomy and whose histories are analyzed in Table I.

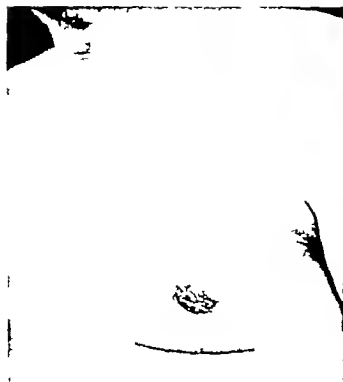


Fig. 11. Case 6. The nipple is gradually returning to normal. The skin ulceration has healed over. The cutaneous metastases are regressing. The swelling in the axilla is unchanged. Note the loss of hair compared with Figure 9. This is the condition 5 months after orchietomy.



Fig. 12. Case 6. There has been decided regression in the extent and density of the pulmonary metastases.

SUMMARY

In summarizing this group we may comment briefly on Case 2, the primary operable patient who became inoperable about 7 months after radical mastectomy. He was treated with progynon after orchietomy was refused and osseous metastasis had appeared. He had an associated cirrhosis of the liver. When the pain from the metastatic deposits in bone became unbearable he agreed to castration. The operation was performed under local anesthesia without incident but the patient died suddenly 3 days after orchietomy. Obviously the effects of castration could not be studied in this case.

In Case 5, the patient, a young man of 39 years admitted to the clinic with widespread disease of the skeletal system and intense pain submitted to bilateral orchietomy surviving for 4 months. In the postcastration period there was no relief of pain and no evidence of reparative change in the skeletal metastases. It may be that his comparative youth contrasted with the four older males in this group who have had favorable clinical responses may be the reason for the unsatisfactory re-

To date no data on laboratory animals have been found which parallels the present clinical study. If it did exist we believe that such studies would be inconclusive for we may reasonably infer that there exists at present no relationship between animal research and human experiment in such a problem.

We must call attention to the relatively small number of male patients with mammary cancer available in the clinic. From this group a smaller number have been considered suitable for the type of therapy under report. And from these few an even smaller group have been obtained who would consent to undergo surgical castration.

One may reason that if the procedure is of value in inoperable cases of male breast carcinoma, it might prove a beneficial form of therapy alone or as an adjunct measure in the treatment of operable breast cancer in the male. We cannot as yet justify it.

TABLE I

[illegible]

TABLE II—METABOLIC EFFECTS OF ORCHIECTOMY

Patient	Disorder	Period, day	Plasma volume, ml	ECW, L ¹	Serum concentration, MEq/L of					
					N	K	Ca	HCO ₃	CL	PO ₄
J S	Carcinoma prostate	Control	3030			3		26	5	3.8
		Postoperative	2970			3		26	100	
P	Carcinoma breast	Control	930		1.4			27	85	
		Postoperative	1000		20	3	6		94	
A P	Carcinoma breast	Control	3300	1.8	6.6		6	26	70	5
		Postoperative	3500		20	6		25	7	
F	Carcinoma prostate	Control	30				6	20	100	7
		Postoperative	45							
J L	Carcinoma prostate	Control	3000				5	23.8	97	3
		Postoperative	26							

ML, milliliters.

ECW, L¹ Liters of extracellular water.

MEq/L, milliequivalents/liter.

This unusual approach to the control of mammary carcinoma in the male has resulted in the following observations: (1) A radical axillary dissection 10 months after local excision and castration revealed no evidence of metastasis to the axillary nodes. (2) There has been no recurrence at the site of the local excision and the patient has not developed distant metastatic areas to date. However one cannot be certain that local excision alone might have controlled the tumor process.

In Case 6 patient was castrated in January 1944 following the discovery of definite pulmonary metastasis on his initial visit to the clinic. Five months after operation there has been a noticeable decrease in the extent and character of the pulmonary metastases. A single area of bone destruction in the crest of

the right ilium has shown no further progression. The primary tumor in the breast has shown moderate healing and regression but the axillary metastases have as yet shown no signs of alteration. There have been no significant changes in the blood chemistry. The patient has maintained his weight and is in good general condition.

METABOLIC EFFECTS OF ORCHIECTOMY

It is now a common observation that after orchietomy patients with carcinoma of the prostate which has metastasized to bone often show considerable clinical improvement. This benefit as a rule consists of a marked decrease of pain at the sites of skeletal metastases, increased appetite, gain in weight and muscular tone. Improvement of this nature likewise was noted to occur after operation in 4 of the 6 patients with breast cancer included in the present study.

The symptomatic change after orchietomy most likely is related to the hormone imbalance effected by the surgical procedure. The nature of this imbalance is not of course, clear but it is reasonable to believe that metabolic changes are affected by a decreased androgen formation or overactivity of naturally occurring estrogens. The latter assumption appears all the more likely since the administration of estrogens to patients with prostatic cancer metastatic to bone in many instances is attended by equal or better success than that induced by orchietomy (7). Since the administration of certain estrogens

TABLE III—METABOLIC EFFECTS OF ORCHIECTOMY

Patient	Disorder	Period, day	Average nitrogen balance, gm per day	Average creatinine output, gm per day	Total creatinine output, gm
J	Carcinoma prostate	Control	-6		
		Postoperative	+6		97
F	Carcinoma breast	Control	-9	91	44
		Postoperative	-6	66	47
A P	Carcinoma breast	Control			
		Postoperative		69	47
G F	Carcinoma prostate	Control			
		Postoperative			
J L	Carcinoma prostate	Control			
		Postoperative	40		

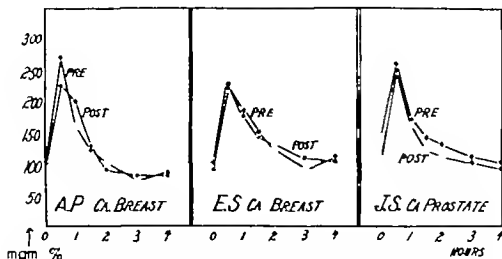


Fig. 13. Intravenous glucose tolerance curves before and after orchiectomy show no change in the carbohydrate utilization. A. P., Case 6 E. S. Case 4 J. S. prostatic cancer whose glucose tolerance was likewise unchanged after orchiectomy. Intravenous glucose, 0.5 gram per kilogram.

and other related steroids apparently can induce characteristic metabolic changes these alterations were sought for after orchiectomy in 2 of the 6 men with breast cancer and in an additional 3 patients with carcinoma of the prostate.

In particular measurements were made of the effects of the surgical procedure on

A Fluid and electrolyte balance Previous studies from this hospital have demonstrated that the administration of α -estradiol benzoate to women before and after the menopause and to men with prostatic cancer induces a significant rise in both extracellular water and plasma volume (2). It is interesting to note that a similar change results from the administration of large amounts of testosterone and testosterone propionate (3). However from 12 to 18 days after orchiectomy no significant change had occurred in the volume of extracellular water or plasma in 2 patients with cancer of the breast and 1 patient with carcinoma of the prostate. Likewise in the 2 remaining patients with prostatic carcinoma in whom these measurements were made only 3 months after operation the values obtained were within normal limits (Table II). Furthermore orchiectomy apparently had no persistent effect on the concentrations of sodium, potassium, calcium, bicarbonate, phosphate, or chloride in the serum of the patients studied.

B Nitrogen balance and protein fabrication The now well known effect of certain androgens (principally testosterone and testosterone propionate) to induce nitrogen retention (6) suggested that a temporary negative nitrogen balance might obtain in males subjected to castration. In a group of 3 individuals studied here (2 with carcinoma of the breast and 1 with carcinoma of the prostate) nitrogen balance studies were made for from 12 to 18 days before and for a like period after operation. No change in nitrogen balance was found to have occurred in this time. The total circulating protein of these individuals likewise remained unaltered (Table III).

C The urinary excretion of creatine Since testosterone and methyl testosterone especially appear to exert a considerable influence on the urinary excretion of creatine (4) there was reason to believe that this function might be effected by the castration. This was not found to be the case in the 2 patients with breast cancer and the 1 patient with carcinoma of the prostate. Likewise the 2 other individuals with prostatic tumor excreted only normal amounts of creatine (Table III).

D The utilization of carbohydrate There is no satisfactory evidence that hormones particularly potent as androgens or estrogens exert an influence on carbohydrate metabolism as do corticosterone or certain other steroids of adrenal cortical origin. Nevertheless, it ap-

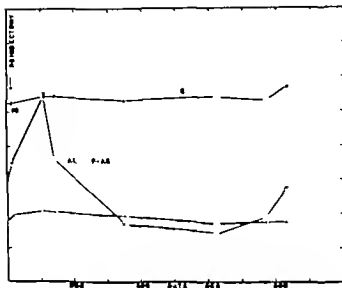


Fig. 4. Case. The serum alkaline phosphatase rose following orchietomy then fell to normal, and remained in the normal range until there was clinical evidence of relapse. Serum calcium and phosphorus are normal throughout. Serum alkaline phosphatase in Bodansky units per 100 c.c. Serum inorganic phosphorus in mgm. per 100 c.c. Serum calcium in mgm. per 100 c.c. Urine calcium in mgm. excreted per 24 hours.

peared to be of interest to ascertain whether or not the hormone imbalance conceived to occur after orchietomy might be reflected in an unusual carbohydrate utilization.

Accordingly 2 patients with carcinoma of the breast and 1 patient with carcinoma of the prostate were maintained on consistent diets as described by Thorne (14). When these subjects were in nitrogen balance, an estimation of their carbohydrate metabolism was obtained from their intravenous glucose tolerance curves both before and after orchietomy. These measurements, made by the technique described by Thorne and associates (14) failed to indicate any change in carbohydrate utilization (Fig. 13) after operation.

SUMMARY

It would appear therefore that of the metabolic phases measured none changed significantly in the 12 to 18 days after orchietomy in the patients studied. Changes known to be induced by testosterone or α -cat radiol apparently do not occur simultaneously with clinical symptomatic improvement in patients subjected to orchietomy.

BIOCHEMICAL EFFECTS OF ORCHIECTOMY

Before the blood chemical findings on the present cases are discussed it will be well to review the general significance of chemical changes in patients with cancer metastatic to bone. Alkaline phosphatase is produced in large amounts in bones which are attempting to repair damage. When cancer of soft part origin metastasizes to bone the bone may or may not respond to the injury with the production of new osseous tissue. When an attempt at repair is made the alkaline phosphatase of the serum rises and the metastases are osteoplastic. When as in the majority of bone metastases from carcinoma of the breast, no attempt at repair is made, the alkaline phosphatase of the serum remains normal, and the lesions are osteolytic. If the process of bone destruction is very rapid the calcium and phosphorus of the serum may rise to high, or even dangerous, levels. Thus the alkaline phosphatase of the blood may be taken as an index of the rapidity of bone formation, and the calcium and phosphorus of the blood as an index of the rapidity of bone destruction.

We have shown elsewhere (10) that treatment with either testosterone propionate or with estrone caused an increase in the serum calcium of female patients with carcinoma of the breast metastatic to bone. The increase was apparently due to increased osteolysis caused by rapid growth of the tumor in the bone. It did not occur in patients with breast cancer who were without bone metastases.

Several investigators (7, 11, 13) have found that when patients with carcinoma of the prostate metastatic to bone are orchietomized, the serum alkaline phosphatase which is usually elevated before treatment rises still higher. In our series, this rise occurred in two-thirds of the cases. A similar rise was observed in patients treated with stilbestrol but only in about one fourth of the cases. The increase was temporary, persisting for only 2 or 3 months and was followed by a drop to or below the initial level. The increase in the serum alkaline phosphatase was usually associated with an increase in the degree of osteoplasia of the bone lesions, but in some patients this appeared to indicate healing while in others the metastatic lesions became larger and more numerous.

It seems probable that the regenerative capacity of the injured bone is stimulated by some one of the many endocrine changes associated with castration. The effect is not confined to the male sex, since we have also seen it in female patients with carcinoma of the breast who have undergone either surgical or roentgen castration. The mechanism of this stimulation remains obscure.

Of the patients forming the subject of the present report Case 1 showed changes in serum alkaline phosphatase very similar to those commonly seen in castrated patients with carcinoma of the prostate metastatic to bone. The alkaline phosphatase was slightly elevated at 5.9 units per 100 cubic centimeters before castration, began to rise immediately after operation and reached 11.0 units in 3½ months. It then dropped, reaching normal in 1 year and remaining within normal limits for another year. There was no striking increase in the degree of osteoplasia of the bone lesions, but the process was arrested and some healing took place. The serum calcium and phos-

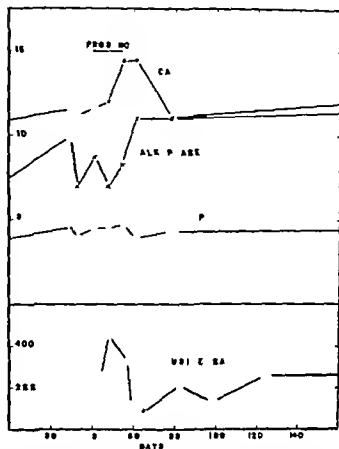


Fig. 15. Case 2. The serum calcium and the urinary excretion of calcium rose during progynon treatment and then fell to their former levels. Changes in serum alkaline phosphatase were difficult to interpret owing to concurrent cirrhosis of the liver. Serum alkaline phosphatase in Bodansky units per 100 c.c. Serum inorganic phosphorus in mgm. per 100 c.c. Serum calcium in mgm. per 100 c.c. Urine calcium in mgm. excreted per 24 hours.

phorus were within normal limits throughout indicating that the rate of bone destruction was over very rapid. At present 28 months after castration the serum alkaline phosphatase has risen slightly, and there are x ray indications of possible relapse. The chemical changes are shown graphically in Figure 14.

In Case 2 there was considerable elevation of the serum alkaline phosphatase throughout the period of observation. The patient probably had cirrhosis of the liver and in liver disease alkaline phosphatase may be retained in the blood instead of being excreted in the bile as it normally is. Hence in this case the level of serum alkaline phosphatase cannot be taken as an index of bone activity. The serum calcium however showed a highly significant rise during α -estradiol therapy. Before treatment the serum calcium was normal varying

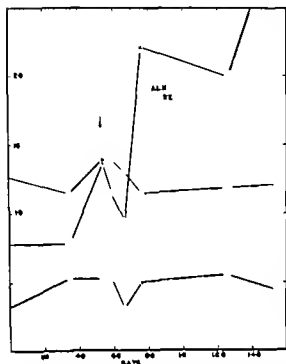


Fig. 6 Case 5 Serum alkaline phosphatase, phosphorus, and calcium are all elevated before orchiectomy and showed only transitory improvement following operation (indicated by arrow). Serum alkaline phosphatase in Bodansky units per 100 c.c. Serum inorganic phosphorus in mgm. per 100 c.c. Serum calcium in mgm. per 100 c.c. Urine calcium in mgm. excreted per 24 hours.

between 10.9 and 11.4 milligrams per 100 cubic centimeters on three determinations. It began to rise immediately on the beginning of treatment, and reached 14.4 milligrams per 100 cubic centimeters in 2 weeks. Treatment was then discontinued and the calcium fell slowly to 11.0 milligrams. The rise in serum calcium was probably due to increased osteolysis caused by the acceleration of the growth of the metastatic tumor under the influence of α -estradiol. The chemical changes are shown in Figure 15.

In Case 3 patient showed occasional slight elevations in serum alkaline phosphatase and serum calcium but the changes were too small to be significant.

In Case 5 patient showed prior to castration, elevations in serum alkaline phosphatase (7.4 to 13.6 units per 100 c.c.) in serum phosphorus (3.2 to 5.1 mgm. per 100 c.c.) and in

urinary excretion of calcium (420 to 580 mgm. every 24 hours). This appeared to indicate that osteolysis was rapid as was also shown roentgenographically but that some attempt at bone repair was being made. Immediately after castration there was a shift toward normal in all chemical findings, but this change lasted for only 2 weeks after which there was a reversion to or above the former high levels. Simultaneously there was a deterioration in the clinical condition of the patient. It is not clear whether the rise in alkaline phosphatase was a response to castration or to the increased activity of the metastatic deposits in the bones. The chemical changes are shown in Figure 16.

In Case 6 patient developed bone metastases late in the period of observation. His blood chemistry was normal except for a persistent borderline elevation in serum calcium. The elevation was too small to be considered definitely pathological.

Determinations of serum acid phosphatase were made at intervals on these patients and no abnormalities were found. This was to be expected, since, as far as is known at present, serum acid phosphatase is never increased except in the presence of metastasizing carcinoma of the prostate.

CONCLUSION

We may summarize the clinical results of this study by stating that bilateral orchiectomy may have been responsible for the temporary regression of the primary lesion in 2 instances, quite striking in 1 of the cases. It has possibly prevented recurrence in the primary operable patient treated only by local excision, and may have prevented local recurrence in 1 other instance. The procedure has caused regression and repair in the secondary deposits in bone as well as in lung. The clinical regressions in this study compared with those reported for inoperable and metastatic carcinoma of the prostate have had in some cases the same dramatic cessation of pain caused by bone involvement. The clinical improvement has been as satisfactory and as long. In fact, we think this procedure for male breast cancer may parallel the striking results of orchiectomy for the advanced cases of prostatic cancer. One in

operable case has now survived 28 months after castration and one 13 months. Both are in excellent states of nutrition and are free from pain. Two have lived for nearly 6 months with regression of their disease and give clinical promise of surviving for equally long periods. Two of the patients have shown definite reparative changes in metastatic deposits in bone, while one with a solitary area of bone involvement has shown no evidence of progression of the disease nor have other areas developed since castration. This latter patient has had regression in the extent of his pulmonary metastases. In two instances the primary lesions have become smaller. The case of longest survival shows only a cicatrix and the other regression in the ulceration and in the cutaneous nodules. The latter patient has not survived a long enough time to evaluate properly the effect of orchietomy on the breast tumor.

In the histological examination of the testes of the 6 orchietomized patients essentially normal gonads were found. The mammary cancer had not metastasized to the testicles. This is in striking contrast to the findings in 33 women who were castrated for therapeutic control of breast cancer. In this group 9 patients had mammary carcinoma metastatic to the ovaries.

The studies on two of the orchietomized patients led to a conclusion that of the metabolic phases measured—(1) fluid and electrolyte balance (2) nitrogen balance and serum protein fabrication (3) urinary excretion of creatinine and (4) the utilization of carbohydrate—none changed in 12 to 18 days after operation. This failure to demonstrate changes known to be induced by the administration of testosterone or α -estradiol shows that these changes are not necessary to produce clinical symptomatic improvement.

In one castrated patient the same changes in the serum alkaline phosphatase were seen which were observed regularly in patients with carcinoma of the prostate metastatic to bone following orchietomy. In two castrated patients there were no conspicuous changes in the calcium phosphorus, or alkaline phosphatase of the serum and in one the findings indicated continuing progress of the disease. In the patient treated with α -estradiol there was a rise in serum calcium similar to that found in female patients with bone metastases from carcinoma of the breast who have received estrogens. Thus in this small series of patients there is a marked lack of uniformity in the response to endocrine treatment of the blood changes caused by bone metastases. Further observation will be necessary before the cause of this variability can be determined.

We must again call attention to the small number of cases under report. The value of the procedure will only be determined by observations on a larger group.

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CHOICE OF INCISION IN GALL-BLADDER SURGERY AS A FACTOR IN PREVENTING WOUND DISRUPTION EVisCERATION AND HERNIATION

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CONSTANTLY improving surgical technique has eliminated the hazards and many of the aftermath complications of surgical procedures. Thus, in addition to lowered mortality rate, the period of recuperation has been markedly reduced and prognosis improved.

In spite of advances in technique the surgeon is still frequently faced with the post operative catastrophe of wound disruption, evisceration and herniation. This fact is especially true in regard to abdominal operations involving the right upper quadrant.

The comprehensive report in 1932 of Sokolov of Leningrad analyzing 730 cases of wound disruption with evisceration aroused extreme interest here and abroad as to the causes and prevention of this unfortunate complication. His analysis based on over 1,000 questionnaires sent out to surgeons throughout Europe showed an incidence of dehiscence in 2 to 3 per cent of all abdominal operations.

Bowen, in a review of the American literature up to 1940 found the incidence from 0.24 per cent in White's series of 19,473 laparotomies to 3.05 per cent in Hinton's series of 621. The mortality rate ranged as high as 75 per cent, although the general average was from 25 to 40 per cent in the various series of cases.

The factors which contribute to wound disruption may be inherent either in the patient or in the technique employed at operation. I am inclined to think that the surgeon can assume responsibility for both eventualities. Certainly in view of the high mortality rate alone he is honor bound to study the possible cause and prevent their occurrence in so far as he is able.

From the reported literature, it may be discerned that neither sex nor age plays a distinct rôle. Rupture may occur at any time

during the postoperative course but it is more usual during the first 2 weeks, more specifically on the eighth or ninth day. Metabolic disturbances such as diabetes, tuberculosis, and nutritional anemia, also general physical debility, emaciation and old age may be considered predisposing causes. This is especially true of malignant lesions, which comprise approximately 25 per cent of disruptions. The far-sighted surgeon will by careful treatment before operation prepare such patients so that they are in the best possible physical condition before surgery is employed.

Infection and drainage, which at one time were considered primary causes of wound disruption have been relegated to a minor position in view of the fact that by far the larger percentage of such cases recover without complications and those that do disrupt represent a small percentage of the total.

Considerable attention has been focused on suture materials as a factor influencing wound disruption. Although there has been heated controversy concerning the undesirability of catgut for suturing because of rapid absorbability and loss of tensile strength, it still has advantages over other materials—still is preferred by most surgeons. Theoretically there is much room for argument about this point. The fact remains, however that disruptions occur regardless of the suture material used.

The digestion of sutures and softening and edema of the tissues accompanying disruption have been attributed by some to escape of pancreatic secretions.

The rôle of sensitivity has been considered as a contributory factor to wound disruptions. Experimental work (3) has shown that sensitivity to catgut can be produced in guinea pigs with resulting gaping of the wound. Clinically such sensitivity has been demonstrated by skin tests. These findings may pertain to a

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few selected cases, but they certainly are not related to the large number of disruptions reported. There has been no substantiation of the allergy factor.

There is no doubt that intra abdominal pressure, such as coughing, sneezing, vomiting and distention contributes to the occurrence of evisceration and herniation. It must be realized, however, that there are many cases in which increased intra abdominal pressure produces no such untoward effects. It is only when tissue impairment already exists that pressure exerts any influence. It must, therefore, be considered a secondary rather than a primary factor. Proper postoperative care can to a large extent eliminate these complications.

It is my opinion that the primary factor in wound disruption with subsequent evisceration and herniation lies in the incision first, in the choice of the incision for the individual patient, then in gentleness in handling the tissues and, last, adequate closure of the wound.

The greater incidence of upper abdominal disruption is probably due to the fact that the abdominal fascia is so distributed that the lower layers of the abdomen are stronger. Next to malignant lesions surgery on the biliary tract has accounted for the major number of wound disruptions reported. It is in these operations on the gall bladder that we at the DeCourcy Clinic have succeeded in the prevention of dehiscence by the individualization of the incision plus the maintenance of good surgical technique. With this procedure we have experienced no wound disruptions in a large series of cases within the past 2 years.

I deem it advisable here to review the principles of wound healing of which every surgeon should be cognizant. The foremost aim in the development of tensile strength of the wound is regeneration of fibrous tissue or fibroplasia as this is commonly called. Then there is proliferation of epithelial and connective tissue cells bordering the incision followed by regeneration of capillaries which penetrate the exudate. This reparative tissue is termed granulation tissue. In the next process the young connective tissue undergoes shrinkage, the cells become spindle-shaped, the newly formed intercellular collagen fibers contract and squeeze the capillary loops into atrophy.

The essential requirements for an incision for operation on the gall bladder and bile ducts are ease of execution and rapidity of closure. It should afford adequate exposure for visibility and manipulation of abdominal organs permitting enlargement if necessary.

Certain anatomic principles should not be overlooked. The incision should traverse muscle rather than fascia, as the scar left in the peritoneum is best protected by muscle. The muscles should be split in the direction of their fibers rather than cut through. The rectus muscles however may be cut transversely without seriously weakening the abdominal wall as such a cut passes between two adjacent nerves without injuring them. No nerves should be divided.

In referring to the literature we find a for midable array of types of incisions for gall bladder surgery both anatomic and nonanatomic. I do not here intend to discuss them all but shall concentrate only on those we popularly employ, namely (1) hockey stick (Mayo-Robson), (2) right rectus (Kammerer), (3) midline (Kammerer), (4) right rectus (high Deaver) and (5) transverse incision.

The hockey stick or Mayo-Robson incision is made through the right rectus near its outer border in a line parallel with its fibers. The incision starts at the costal margin and extends vertically downward for from 5 to 8 centimeters. The upper end is carried obliquely as high as possible in the interval between the ensiform cartilage and the right costal margin. The posterior sheath of the rectus and peritoneum are divided together.

The right rectus incision of Kammerer starts at the level of the umbilicus, half an inch medial from the lateral border of the right rectus muscle. It runs upward along the lateral border of this muscle to the costal margin. The skin, superficial and deep fascia and the anterior sheath of the rectus muscle are cut longitudinally. The incision of the deep fascia is made approximately three-quarters of an inch closer to the midline. The rectus muscle is retracted inward from the outer edge of rectus or outward from the midline. The posterior sheath and peritoneum are cut longitudinally. The value of this incision depends on the fact that the rectus is not cut and that this muscle

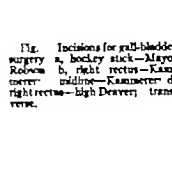
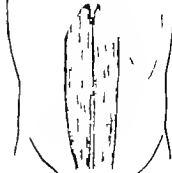


Fig. Incisions for gall-bladder surgery
a, hockey stick—Mayo-Robson
b, right rectus—Kammeter
c, midline—Kammeter
d, right rectus—high Deaver; transverse.

protects the incisions in the peritoneum and fasciae after the wound is closed.

The midline incision which has been in use for the longest period of time presents the advantages of rapid opening and closure and gives a good view of the entire abdomen. For this reason it is an excellent incision for exploratory purposes. The objectionable feature of the incision is that it cuts the linea alba, i.e. the terminal fibers of the aponeurosis of all lateral muscles perpendicular to their course. To avoid the ligamentum teres, the incision at the level of the umbilicus flanks slightly to the left of the midline on to the muscle, but ends at a point parallel to the umbilicus.

The right rectus incision of Deaver starts at the level of the costal margin one-fourth to one half inch medial from the outer border of the right rectus muscle. It runs downward to approximately 1 inch below the umbilicus.

The skin, fascia and the muscle fibers are split longitudinally.

The transverse incision starts about 1 inch to the right of the midline and directly outward about 2 inches below the costal margin parallel to the "fissures of Langer." The external fascia of the rectus muscle is cut across in the same direction while the fascia of the external oblique muscle is split in the line of the fascial fibers. With the fingers inserted between the exposed rectus muscle and the posterior sheath of the rectus, two arteries usually found in the rectus muscle can often be palpated and ligated before the muscle is incised. The rectus muscle is then split across its entire breadth. The deep oblique muscle and the transversalis muscle are split in the direction of their fibers. The peritoneal cavity is opened transversely.

With the years the trend of many surgeons



Fig. 2. Exposure of gall bladder through vertical incision showing folding of liver on elevation.

has become more and more away from vertical incisions in gall bladder surgery. Some have even adopted the transverse incision exclusively. This appears to me to be an extreme measure as the vertical incision presents certain advantages over the transverse incision. I wholly disagree with surgeons who suggest that the transverse incision be used in all operations on the gall bladder. At the DeCourcy Clinic we have employed this incision satisfactorily in approximately 50 per cent of cases.

Our choice of operation depends upon the physical structure of the individual. For the asthenic type of individual i. e. the thin long chested person we have found that the necessary higher exposure can best be obtained with the vertical incision.

The transverse is our incision of choice in the obese individual. This not only gives excellent exposure but also carries less trauma causes less embarrassment to respiration and allows the liver to be elevated without folding on itself. This latter point is doubtless a great advantage in dealing with the obese patient as we have often experienced such diffi-



Fig. 3. Exposure of gall bladder through transverse incision.

culty when we have had to contend with a thick abdominal wall.

Because of the limited exposure provided by such an incision it does not allow for exploration as when employing the McBurney incision for appendicitis the diagnosis must be certain before the operation is performed.

The vertical incision on the other hand gives excellent exposure and is ideal for exploratory purposes. The main objection is the difficulty of closure which we seem to have been able to surmount. It is well known that the midline incision traverses the linea alba which is poor in its blood supply. For this rea-

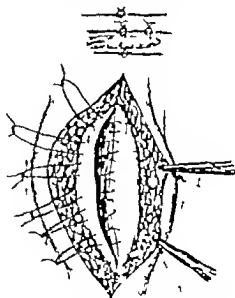


Fig. 4. Overlapping of fascial layers (Blake) when vertical incisions are used.

son a sudden or unusual contraction of the transverse or oblique muscles of the abdomen especially when intra abdominal pressure is exerted would tend to pull it apart. The value of the right rectus incision lies in the fact that the muscle protects the incisions in the peritoneum and fasciae after the wound is closed and there is little damage to the nerve supply.

We have entirely eliminated the difficulty involved in closure of vertical incisions by employing a Blake closure of the fascia, just as performed in a secondary operation for incisional hernia. It is surprising with what ease this can be done at the primary operation. When the abdomen is entered the fascia is stripped on both sides and overlaid as sutured. Drainage when necessary is brought out through a separate stab wound. The actual extra time consumed in the stripping and closure without undue haste amounts to 10 minutes.

All incisions are closed by careful approximation of anatomic structures. Tension is avoided and gentleness in the handling of tissues is stressed.

The fact that employing the technique described we have been able to prevent wound disruption, evisceration and herniation after surgery on the biliary tract has prompted me to report these findings, especially since many surgeons are leaning to the indiscriminate use of the transverse incision in all cases.

CONCLUSIONS

It is within the surgeon's power to prevent the occurrence of wound disruption, evisceration and herniation which frequently occur in operations involving the right upper quadrant.

By individualizing the type of incision used by careful handling of the tissues and by adequate closure of the wound, this major catastrophe has been eliminated in a large number of gall bladder operations which have been performed within the past 2 years in my clinic.

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PAPILLARY CYSTADENOMA LYMPHOMATOSUM (WARTHIN'S TUMOR) OF THE PAROTID SALIVARY GLAND

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PAPILLARY cystadenoma lymphomatousum does not constitute a serious or complicated problem in a tumor clinic. These benign tumors cannot be differentiated from mixed tumors of the parotid by clinical examination alone and in most cases a specific diagnosis is not made until after a surgical specimen has been examined. Nevertheless papillary cystadenoma lymphomatousum makes up a definite percentage of all parotid tumors and when the surgeon receives the histologic diagnosis from the pathologist he will be called upon to give the prognosis and his recommendations as to the necessity for further care and follow up examinations.

The present study was undertaken to determine the clinical behavior of these tumors and is based upon a series of cases of papillary cystadenoma lymphomatousum culled from the records of 359 parotid tumors all observed in the Head and Neck Service of the Memorial Hospital from 1932 to March 1944 inclusive.

Definition The term papillary cystadenoma lymphomatousum as used in this paper designates an essentially benign cystic tumor occurring either in or attached to the parotid salivary gland. Its microscopic appearance is characterized by specific epithelial structures supported by a lymphoid stroma.

Other terms, that have been employed to designate this neoplasm are adenolymphoma, branchiogenic adenoma, epitheliolymphoid cyst, branchioma, cylindrocellular branchiogenic adenoma, orbital inclusion adenoma and onkocytoma.

In 1910 Albrecht and Arzt first established this tumor as a distinct morphologic entity. There have since been reported 66 genuine cases exclusive of the present series. In 1929 Warthin discussed the cases already in the

literature and added 2 of his own. He gave an excellent description of their pathology and from then on the growth has often been referred to as Warthin's tumor an eponym hardly justified from the standpoint of precedence. Although the term papillary cystadenoma lymphomatousum contributed by Albrecht and Arzt is reasonably accurate from a descriptive standpoint nevertheless it has the disadvantage of being long and cumbersome so that the figurative designation of Warthin's tumor already in common usage will probably continue to be employed as a matter of convenience.

ETIOLOGY

Incidence Although papillary cystadenoma lymphomatousum is a somewhat uncommon neoplasm in general hospital admissions it will be found to make up a definite percentage in large series of parotid tumors. On the Head and Neck Service of the Memorial Hospital where about 1600 new patients with neoplasms are admitted yearly 359 tumors of the parotid salivary gland (206 benign and 163 malignant) were observed during the period from January 1932 to March 1944 inclusive. The 22 cases of papillary cystadenoma lymphomatousum herein reported comprise 10 per cent of benign parotid tumors, 6 per cent of all parotid tumors and less than 2 per cent of all neoplasms of the head and neck. This incidence is in accordance with the observations of Swinton and Warren and others.

Age and sex In this series at the time of admission the oldest patient was 73 years of age and the youngest was 30 years of age the average age was about 53 years. There were 20 males and 2 females (ratio 10 to 1). This is in accordance with the observation of others that the tumor occurs characteristically in middle aged and elderly males. It is of interest to note that the 2 female patients in our series were 36 and 37 years of age respectively on

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Fig. General microscopic structure of papillary cystadenoma lymphomatosum, showing characteristic double layered epithelium, lymphocytic stroma, cystic pattern, and intracystic papillae.

admission as compared to the average of 53 years. The most likely explanation for this age-sex discrepancy is that the tumor tends to produce facial and cervical disfigurement early in its course and females will, accordingly seek consultation sooner. No satisfactory explanation has been advanced in regard to the predominance of papillary cystadenoma lymphomatosum in males. The incidence of salivary gland tumors, in general, is about equal in the two sexes.

The youngest patient whose case is described in the literature was a boy $2\frac{1}{2}$ years of age, reported by Stoehr and Risak. The oldest patient was a male of 92 years, reported by Carmichael, Davie, and Stewart.

Causative factors. An analysis of our cases did not reveal any common causative factor. No history of trauma, previous infection or calculous disease was obtained. The association of a papillary fibroma of the tongue (Case 2) nasal polyps (Case 6) lymphosarcoma of the neck and mediastinum (Case 8) capillary hemangioma of the face (Case 9) carcinoma of the stomach (Case 10) and ganglion of the wrist (Case 19) appeared to be merely coincidental.¹

¹ All case numbers. This report refers to our series.

PATHOLOGY

Gross pathology. Cystadenoma lymphomatosum is an encapsulated tumor. The capsule is thin, strong glistening and is traversed by fine blood vessels. Rarely however the tumor may not be completely enveloped by a capsule, and, in such an instance the neoplasm may infiltrate parotid substance for a short distance (Case 16). In our series, the specimens varied from 1.5 to 5.5 centimeters in greatest diameter and were plumply ovoid and globular. The surface is either smooth, finely bosselated or divided by branching clefts into pseudolobular pattern. The consistency is soft in some places, and fluctuant in others, although an occasional tumor may be firm throughout.

In most cases, when a Warthin tumor is opened a chocolate-colored material, sometimes of mucinous appearance exudes from the cut surface. When this material is scraped away with a knife the tissue presents a glossy or an opaque appearance, and the color varies from pink, to yellow to brown. Most often, the cut surface is coarsely pseudolobulated, and contains several cysts varying from 1 millimeter to about 2 centimeters in diameter. These cysts are lined with shaggy tissue composed of papilliferous projections and some-



Fig. 2. High power microscopic appearance of the epithelium in Warthin's tumor showing an outer layer of tall columnar cells and a basal layer of cuboidal cells. The nuclei are large and coarsely granular. In the cylindrical layer they are situated at the luminal end of the cells. The underlying lymphocytic stroma is abundant.



Fig. 3. Papillary cystadenoma lymphomatosum showing intracystic papillae which are covered by characteristic double layered epithelium. The lymphoid stroma contains fully developed germinal centers.

times the locules are completely filled with papillary tissue. The shaggy appearance of the lining of the cysts is the most striking naked eye characteristic of cystadenoma lymphomatosum. The papillary lining becomes more prominent after the specimen has been

washed with water. Occasionally a tumor is encountered whose cut surface is not multiloculated. The growth is often mottled by yellowish flecks and tiny areas of hemorrhage.

In our series, the growths were all situated beneath the fascia overlying the parotid gland



FIG. 4 Photograph (Case 9) showing common location for papillary cystadenoma lymphomatosum (Intra-auricular). This neoplasm is found to lie posterior to the tail of the parotid gland.

(deep cervical fascia) but the relation of the neoplasm to the gland was variable. In 9 cases, the tumors were superficial but attached to the parotid capsule. In 7 cases, the neoplasms were found to lie beneath the parotid capsule and embedded within salivary gland tissue at varying levels. In 4 instances, the tumors were located posterior to the parotid gland and in these cases, it was necessary to elevate the tail of the parotid gland in order to expose the growth. There were 2 cases in which the growths were attached to the tail of the parotid gland, thus lying in the upper neck, and in close relation to the superior pole of the thyroid gland. These tumors could easily have been mistaken for adenomas of the thyroid gland.

Although we could clearly demonstrate that the Warthin tumors, in our series, lay definitely in the parotid area, the growths often extended to involved adjacent structures especially after attaining considerable proportions. In Case 14 the tumor was not only

retromandibular and situated beneath the sternomastoid muscle, but it extended upward almost to the lateral wall of the pharynx. This neoplasm measured 5 centimeters in its greatest diameter but was, nevertheless, completely encapsulated.

Histopathology Papillary cystadenoma lymphomatosum is composed of tissue not found normally in the salivary glands, and its microscopic appearance represents a specific morphologic entity. It is characterized by papillary epithelial structures embedded in a lymphoid stroma. The papilliferous projections are covered by a peculiar eosinophilic, palisade-like epithelium and, together with its supporting lymphoid stroma, are the most striking histologic features of this neoplasm (Figs. 1 and 3).

The general arrangement may be tubular, alveolar or cystic, but is usually a combination of all three. The intracystic papilliferous projections vary from simple stalks or tufts to complex branchings. The spaces are lined by characteristic epithelium which is arranged in a double row of tall, evenly placed cylindrical cells resting on a thin basement membrane. The inner row of the cells is frequently cuboidal. Occasionally a single row of cells is encountered but the epithelium may also be heaped up. The cytoplasm is abundant, pale pink and finely granular. The nuclei are large, most often spherical but occasionally elongated and vesicular; they are situated at the luminal end of the cells (Fig. 2). The nuclei stain deeply, possess a distinct nuclear membrane and, very often, a large nucleolus. Warthin has maintained that the epithelium is ciliated, but, except for Robinson and Harless, no other investigator has been able to confirm this observation. Cilia were not demonstrated in any of our specimens. Many of the gland spaces contain a pink amorphous material and some of the spaces are filled with debris and pyknotic nuclei.

The stroma may vary from scant lymphocytic infiltration (Fig. 3) to true lymphoid tissue containing fully developed germinal centers; the lymphoid stroma seems to be molded into the papillary stalks and tufts, and at no time is it compressed or distorted by epithelial elements. This suggests that the

lymphoid element is an active part of the tumor. Occasionally the lymphoid follicle may undergo partial, or complete hyalinization. Little connective tissue is seen but when present it appears loose and relatively avascular. Not infrequently broad sheets of hyalinized connective tissue are observed, especially in those tumors which contain scant lymphoid stroma.

The capsule although thin consists of dense fibrous tissue with an occasional bit of salivary gland tissue attached to it. No salivary glandular tissue was encountered within the tumor nor was there any instance in which the tumor was found actually to invade the parotid gland. In Case 16 the growth was not completely encapsulated and to the naked eye appeared to infiltrate the parotid gland for a short distance. Microscopic examination however did not reveal true invasion of the gland by tumor tissue.

A histologic variant in our series occurred in Case 7 in which atypical areas were seen. In many places the epithelium was heaped up and there was a loss of orientation between the epithelium and stroma but true malignant transformation was not observed in any section. The only reported instance of anatomic malignant transformation is by Ssobolew. Notwithstanding in our opinion the submitted evidence in this case is not convincing and does not justify a diagnosis of malignant papillary cystadenoma lymphomatousum.

Jaffé has described secretion capillaries between the epithelial cells with evidence of secretory activity and attributed the transformation of dilated glands into cysts to this secretion phenomenon. This has been confirmed by Freshman and Kurland and by Wood. Staining techniques for the demonstration of intercellular capillary spaces were not carried out in any of our specimens.

Histogenesis. Many sources have been suggested to account for the origin of papillary cystadenoma lymphomatousum including branchial arches, parotid lymph nodes, eustachian tube, oncocytic cells, orbital inclusion and embryonal buccal ectoderm. It has even been suggested by Lecène and Brachetto-Brian that the growth represented the development of an ectopic tonsil. While no single



Fig. 5. Sialogram in Case 5. The ductal system of the parotid gland has been distorted due to extrinsic pressure produced by Warthin's tumor. Note large central defect and whorl-like appearance on the periphery.

hypothesis has been advanced which satisfactorily explains the genesis of the neoplasm, the various theories of histogenesis are briefly described in the following paragraphs.

1. *The branchiogenic theory* was first proposed by Ssobolew and has been favored by Askaniy, Rickl, Ewing and others. These observers contend that the tumor has its origin from the ectodermal portion of a branchiogenic arch because of its resemblance to the embryonal type of epithelium and lymphoid stroma found in the ordinary branchiogenic cyst. Furthermore its epithelium has been said to resemble the eosinophilic cells of the parathyroid glands. No convincing evidence however has been furnished to support this hypothesis.

2. Warthin suggested that the tumor might arise from heterotopic pharyngeal ectoderm, possibly the *eustachian tube* and he has been supported by Wendel. This theory too is based on similarities in the epithelium.

3. According to Kraissl and Stout, a definite structure—the *orbital inclusion*—which gives rise to the orbital salivary glands in certain carnivora appears as a vestigial rudiment in human embryos. During the growth of the embryo the parotid gland comes to lie in close proximity to this vestigial epithelial lymphoid structure whose lining cells are supposed to



Fig. 1. A histological section showing a lymph node with a central area of dense staining, possibly representing a lymph node or a glandular structure.

resemble the epithelium of cystadenoma lymphomatosum. These investigators maintain that the peripheral origin of the tumor is from a dilatation and proliferation of the orbital lymph node. This theory is attractive in that it tries to account for the lymphoma as well as the epithelial element of the tumor. For most authors agree that the lymphoma tissue takes an active part in the formation of the neoplasm. One objection to this hypothesis is that the orbital lymphoma has been demonstrated in man.

4. The theory that the tumor arises from heterotopic salivary gland rests situated in lymph nodes adjacent to the parotid gland was first expressed by Albrecht and Arat. This hypothesis (derivation from heterotopic rest) tends to support the morphologic impression that the lymphoma component is part of the growth and does not represent remnants of a lymph node. It also explains in part why the tumors may be encountered within or attached to the parotid salivary gland. Anatomic evidence has been submitted to support this theory. Neisser has described lymph nodes in the parotid gland of a 120 millimeter fetus which contained salivary tubules. He has also demonstrated salivary tissue within preauricular lymph nodes of newborn infants. These ob-

servations have been confirmed by Nicholson (18, 19) Blunting and Tennant (quoted by Plant) and others. Lang claims to have encountered salivary acini and tubules in cervical lymph nodes. Wang (quoted by one of us—MM—20) has observed remnants of glandular acini in cervical lymph nodes which he interpreted as embryonic rest. Since there is reasonable anatomic basis to support the contention that areas of salivary tissue may become lost in parotid lymph preauricular lymph nodes during development of the gland, the hypothesis that cystadenoma lymphomatosum is derived from these heterotopic rest appears to be the most acceptable, but not completely satisfactory explanation for the genesis of this tumor. The main objection to this theory is that conclusive evidence has not been offered to indicate that the lymphoma is due in part to

the presence of heterotopic salivary gland tissue in lymph nodes. The possibility of primary carcinoma arising in lymph nodes has been reported previously. Personal observations in human lymph nodes have shown salivary gland tissue in lymph nodes. In one case, the lymph node was found to contain salivary gland tissue. In another case, the lymph node was found to contain salivary gland tissue. In a third case, the lymph node was found to contain salivary gland tissue. In a fourth case, the lymph node was found to contain salivary gland tissue. In a fifth case, the lymph node was found to contain salivary gland tissue. In a sixth case, the lymph node was found to contain salivary gland tissue. In a seventh case, the lymph node was found to contain salivary gland tissue. In an eighth case, the lymph node was found to contain salivary gland tissue. In a ninth case, the lymph node was found to contain salivary gland tissue. 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a lymph node lymph sinuses were not encountered in any of our specimens nor have they been demonstrated by other investigators.

5 A variation of the theory of Albrecht and Arzt has been proposed by Hamperl and is based on the presence of certain characteristic cells found in the salivary glands which appear by a process of differentiation from both glandular and duct epithelium. They contain a finely granular cytoplasm their nuclei are indented and rich in chromatin and they have even been reported to form hyperplastic nodules. These cells which were first called pycnocytes but, later named oncocytes by Hamperl are supposedly encountered more frequently in individuals over 30 years of age and almost constantly during and after the 6th decade. Jaffé who contributed the term oncocytoma for this tumor has developed the thesis that the growth has its origin from oncocytes in aberrant salivary tissue of lymph nodes adjacent to the parotid gland.

SYMPTOMS AND CLINICAL COURSE

Papillary cystadenoma lymphomatousum is presumably always a rather slow growing tumor that is. It does not reach a size of several centimeters in less than a year usually more. The rate of growth is slow and steady up to a size of 4 to 5 centimeters when further growth has a tendency to be self limited. In our series the patients who gave short histories all admitted that the tumor was at least 2 centimeters when first discovered. The shortest stated duration of the tumor before admission was 2 months, and the longest 12 years. It is probably somewhat coincidental that about one-quarter of our patients gave exactly 3 years as the duration of the tumor. In 50 per cent of the cases the duration of the tumor was more than 1 year. The average duration of 3 years is somewhat shorter than that of benign mixed tumors (6½ years) as observed in our clinic. In only 2 cases was there a history of rapid growth—in the cases of 2 patients with tumors of 4 centimeters in diameter who stated that the masses had been present only 6 to 8 months respectively. Carmichael, Davie and Stewart reported a case which was present for more than 30 years before excision was carried out.

Most of the patients in our series complained of no symptom other than cervical or facial disfigurement. In only 2 cases, was there a history of slight pain at the tumor site associated with recent rapid growth and possibly due to a more rapid accumulation of fluid within the cystic mass. The average patient with papillary cystadenoma lymphomatousum seeks medical advice either because of the unwelcome deformity of the growing tumor or apprehension as to its true nature. The time of seeking medical advice is usually selective.

In our cases the tumors were located most frequently in the midportion of the parotid or in other words just in front of the lobule of the ear. In 13 cases the tumors occurred around the borders of the parotid particularly at the tail of the gland that is just behind and a little below the angle of the jaw or even in the upper neck. The tumors were usually single ovoid and sharply circumscribed varying in size from 1.5 centimeters to 5.5 centimeters. In 3 cases growth occurred bilaterally. There was one instance of homolateral multiple tumors (Case 22) and 1 case in which multiple tumors were encountered bilaterally (Case 20). The distribution between the two sites was about equal.

On clinical examination the growths were all of smooth contour only moderately firm or even slightly fluctuant in consistency. The nodularity and marked induration so characteristic of mixed tumors is not found in papillary cystadenoma lymphomatousum. Except when located in the retromandibular portion of the parotid these tumors are always movable and even though they arise within the parotid in their progressive enlargement they tend to migrate toward and lie on the surface of the gland as do other encapsulated tumors of the parotid. When papillary cystadenoma lymphomatousum arises in the retromandibular portion of the parotid the growing tumor is compressed between the posterior edge of the ascending ramus of the mandible and the mastoid process and the clinical findings will be mainly that of diffuse ill defined fullness of the parotid area due to expansion of the deep lying tumor.

Since the tumor is encapsulated and non-infiltrating there is no change in the appear-

ance of the overlying skin. In our group about 10 per cent of the cases were bilateral and 5 per cent homolaterally multiple. In the literature, we have found 2 cases of bilateral papillary cystadenoma lymphomatosum (Nino and Oughterson, quoted by Plaut) but no previous instance of multiple homolateral occurrence of this tumor has been reported.

The clinical course of Warthin's tumor is essentially benign. In the 2 cases of longest duration 7 and 12 years, respectively there had been little change in appearance for the several years preceding the operation. The tumors tend to recur promptly following incomplete excisions, as was illustrated in Cases 7 and 12 and as reported by Carmichael, Davie and Stewart. Malignant transformation did not occur in any of our cases, and we doubt the authenticity of the one instance reported in the literature.

In our series, the tumors were situated in or attached to the parotid salivary gland. Our records reveal no occurrence of this tumor in the lacrimal salivary glands, or in any minor salivary gland tissue. In the literature there were 3 instances of Warthin's tumor reputedly occurring in the submaxillary gland by Albrecht and Arzt, Spitznagel and Wendel. After a review of these references it seems to us that these cases are not well authenticated. None of these authorities actually stated that the tumors were found in the substance of the submaxillary gland or attached to its anterior surface. The fact that they have not done so indicates that they have not appreciated the fact that the anteroinferior aspect of the tail of the parotid lies in contact with the posterior superior aspect of the submaxillary salivary gland, although the deep cervical fascia separates the two. Since papillary cystadenoma lymphomatosum can so consistently be demonstrated to arise or, at least, to lie in direct contact with the surface or borders of the parotid salivary gland, an error could easily be made from the standpoint of surgical pathology if the tumor arose in the parotid at its point of contact with the submaxillary salivary gland. The fact that, in our series, none of the tumors arose separately from the parotid gland does not prove, of course, that they may not rarely do so. On the other hand, our series

comprises one-quarter of all cases so far recorded and furthermore in our opinion, no conclusive evidence has, thus far, been advanced to indicate definitely the occurrence of Warthin's tumor other than in the parotid gland.

DIAGNOSIS

There are no clinical stigmas sufficiently characteristic of papillary cystadenoma lymphomatosum to distinguish it from certain other much more common tumors of the parotid. We have found no case reported in the literature with a preoperative diagnosis of this specific neoplasm and, in the present series, a clinical diagnosis was not made in a single instance before an aspiration biopsy report was returned or failing that, before histologic examination of the surgical specimen. In our series, the preoperative diagnosis was made by aspiration biopsy in 12 cases as will be discussed later in this report.

Differential diagnosis. Since papillary cystadenoma lymphomatosum is, we believe, always located in the parotid area and possesses such characteristics of a benign growth as long duration, smooth contour, mobility suggesting encapsulation, and lack of infiltration, it will usually and logically be tentatively diagnosed by the experienced examiner as a mixed tumor.

In 4 of our cases where the tumors appeared in the upper neck just on or below the tail of the parotid, the soft, fluctuant character led to the tentative diagnosis of branchiogenic cyst and, in 2 others of the cervical cases, the diagnosis of malignant lymphoma and adenitis, respectively were made. Delangle, Peyron and Roussacloix reported a case in which a tentative diagnosis of carotid body tumor was made before operation which seems to us rather farfetched on the basis of probability and dissimilarity in clinical findings.

There are no differentiating features to distinguish Warthin's tumor from a cellular mixed tumor of smooth contour although, of course, no experienced surgeon would be in doubt as to the true nature of the nodular in duration variety of the mixed tumor. Metastasis from silent primary cancer in the mouth or upper portions of the pharynx may occur in lymph nodes situated in the upper portion of the neck or even overlying the parotid. It is

possible to confuse such lesions with tumors of parotid origin especially if the possibility of silent primary cancer is not appreciated.

Other cystic tumors which occur in the region of the parotid or in the upper neck are cystic mixed tumors cystic carcinoma of the parotid and branchiogenic cysts, the latter often exhibiting walls thickened to 1 centimeter, or more, by lymphoid hyperplasia. As with cellular mixed tumors and lymphomas of the parotid lymph nodes there are no distinguishing features and the diagnosis must be made either by aspiration biopsy or examination of the surgical specimen.

Sialography. Roentgen visualization of the parotid gland after the instillation of lipiodol into the ducts was carried out in 13 cases following the technique of Blady and Hocker and satisfactory sialograms were obtained in 12 cases. The general roentgenographic appearance produced by papillary cystadenoma lymphomatosum was not diagnostic or specific. The findings consisted mainly of slight displacement or distortion of part of the duct system. Since many of the tumors were merely attached to rather than within the parotid gland appreciable sialographic changes were not to be expected. When the growths were embedded within salivary gland tissue especially in the preauricular area, then a significant displacement of the finer ducts could be demonstrated (Fig. 5). Aside from frequently indicating that an encapsulated and probably benign tumor has produced extrinsic pressure on a certain portion of the duct system of the gland sialography was of no great aid as a diagnostic procedure.

Aspiration biopsy (14/15). This procedure was performed in 18 cases. In 12 cases a report of papillary cystadenoma lymphomatosum was returned by Dr. Fred Stewart, pathologist of the Memorial Hospital. In 9 of these a positive report was based on examination of a paraffin section of an aspirated plug of tissue (Fig. 6). A smear of aspirated material is less reliable in establishing a diagnosis of this specific neoplasm. Failure of the positive diagnosis from aspiration biopsy is largely due to the lymphocytic character of the tumor so that in most cases, it is impossible to differentiate normal lymph nodes, malignant lymphomas

chronic adenitis and Mikulicz's disease from Warthin's tumor. There were 5 cases in which aspiration biopsy was negative in spite of the fact that the procedure was repeated in 3 of them.

If aspiration biopsy is to provide a high percentage of correct preoperative diagnoses in papillary cystadenoma lymphomatosum or in most benign tumors the pathologist must be familiar both with the clinical settings of the particular tumors, and with the kinds of tissue together with the histologic variants likely to be found in the different types of benign tumors. Many times the correct diagnosis depends on an intelligent guess on the part of the pathologist whose report may often read that the microscopic findings are merely consistent with the diagnosis of such and such a tumor.

TREATMENT

The treatment of papillary cystadenoma lymphomatosum is by surgery, the tumor being enucleated by sharp and blunt dissection along its capsular wall. Nothing is to be gained by a wider excision so as to include a margin of parotid tissue as a matter of fact such wide excision will almost always result in unnecessary injury to some of the branches of the plexus of the 7th cranial nerve. Extracapsular enucleation is also the proper treatment for other delimited tumors of the parotid and as such need not be specifically selected for Warthin's tumor. In any case deliberate selection of treatment for this particular tumor would not be possible except after a positive aspiration biopsy.

Surgical excision of non-infiltrating encapsulated parotid tumors should always be carried on without too great a period of delay. Under a waiting policy many mixed tumors of the parotid will undergo malignant transformation and metastasis. In obviously benign encapsulated parotid tumors there is nothing to be gained by waiting and should the growth be a mixed tumor then malignant transformation with metastasis may occur before there is any particular indication for operation. If all non-infiltrating encapsulated parotid tumors were treated according to this plan then Warthin's tumor would of necessity be included

TABLE I.—PAPILLARY CYSTADENOMA LYMPHOMATOSUM—TABULATION OF 22 CASES

Case No. Initials Age Sex	Date of admission	Topographic location	Dura mass	Greatest diameter, cm.	Aspiration biopsy	Involved portion of parotid gland	Treatment	Follow-up period without recurrence	Remarks
W R 40 M	1-1-11	Right pre-auricular	mm		Not done	Central (just beneath parotid fascia)	Excision	3 yrs	Not in parotid substance
G M 47 M	1-17-11	Left infra-auricular retro-mandibular	37		Not done	Tail (between sternocleidomastoid muscle)	Excision	3 yrs	Resembled enlarged cervical lymph node
O K 36 F	1-1-11	Left pre-auricular		5	Negative	Central	Excision	6 yrs	
R C M	1-17-11	Left pre-auricular	375	5	Negative, no Papanicolaou	Central	Excision	5 yrs	Dead 4-11-11 coronary thrombosis
W K M	1-14-11	Right retro-mandibular			Positive	T 1	Excision	2 yrs	
J L 41 M	1-1-11	Left retro-mandibular	mm		Negative	Tail	Excision	2 yrs	Adjacent to parotid gland
J L 41 M	7-3-10	Right retro-mandibular	mm		Not done	Central	Not excised because of facial blood-vessels	Recurrent 11/10/11	Recurrent case (microscopically recurrent tumor)
B R 44 M	6-17-10	Right pre-auricular		5	Lymphoid infiltration (rest of parotid)	Central (just beneath parotid fascia)	Excision	5 yrs	Also had lymphosarcoma
C O 46 M	4-10	Right pre-auricular	375		Negative (stic)	Central (just beneath parotid fascia)	Excision	3 yrs	
T K 66 M	1-1-10	Cervical (between right)	75	5	Positive	Posterior to tail	Excision	3 yrs	Presented as neck tumor
J L 43 M	1-1-10	Tail retro-mandibular	mm		Positive	Posterior to tail	Excision	3 yrs	
R S 37 F	1-1-10	Right infra-auricular	37		Negative (recurrence)	Tail	Excision following 5 years' observation	3 yrs	Second recurrence following recurrent excision elsewhere (facial nerve years later)
K O 69 M	9-10-10	Right infra-auricular	375		Not done	Tail	Excision	11 yrs	Presented as neck tumor (last June, 1911, stomach cancer)
J F M	a) 1-1-11 b) 4-1-11	a) Right infra-auricular & retro-mandibular b) Left retro-mandibular	375 6 mm		Not done Positive	Posterior to tail Attached to tail	Excision Excision	3 yrs 37	Posterior to sternocleidomastoid muscle extracted (wall of pharynx) as cyst of neck Bilateral case
H K 6 M	1-17-11	Posterior to left angle of right mandible	mm		Positive	Adjacent to tail	Excision	2 yrs	Presented as neck tumor
A V 6 M	1-1-11	Left retro-mandibular	75		Negative (recurrence)	Tail (deeply embedded)	Excision	116 yrs	Upper portion not encapsulated appeared to infiltrate gland for short distance
C H 54 M	1-1-11	Right infra-auricular	6 mm		Positive	Posterior to tail	Excision	3 yrs	
R R 30 M	8-1-11	Left pre-auricular	375		Not done	Central (between parotid capsule)	Excision	14 yrs	
J A 47 M	1-17-11	Left pre-auricular	375		Positive	Posterior to tail	Excision	37	

the wall of the pharynx. In this case there was temporary paralysis of the 7th nerve due to stretching and manipulation with eventual complete recovery.

Radiation therapy. Inasmuch as the tumor contains abundant lymphocytic components, the question as to its possible radiosensitivity and a preference for radiation therapy might be raised. On the other hand the character of the lymphoid tissue, the presence of the adenoid elements, and the cyst formation do not augur well for the success of radiation therapy. It has been fairly definitely established that hyperplastic lymphoid tissue, in general, is not highly radiosensitive and will not regress under irradiation unless the dosage is high. The question is of little practical import, however, since the results of surgery are so expeditious and satisfactory as to leave almost no indication for any other method of treatment. We have few data as to the effects of radiation therapy in our series. We ourselves, did not employ it. In one of our cases the patient was referred following the application of 1250 r of roentgen therapy (other factors not available) 6 days following an alleged complete excision of a Warthin's tumor. Shortly after this treatment, there was an apparent recurrence for which the patient was referred to our clinic, but the poor physical condition from anemia, due to rectal hemorrhage precluded surgical excision. The patient was followed at regular intervals, and, at the end of the year, was lost to follow up. Several features in this case are so uncertain that we do not think any conclusions should be drawn from it. So far as the literature is concerned, there is no evidence relative to the radiosensitivity or radiocurability of this specific tumor.

Recurrences. In our series of 21 surgical excisions, there have been no local recurrences to date. The tumor does recur however if not completely excised. Drainage of the cyst is not sufficient. In 2 of our cases, there had been incomplete excisions before admission. In 1 case, the tumor had been operated upon twice, 1 year and 1 month, respectively before admission to the Memorial Hospital. After complete excision of the tumor in our clinic, the patient has remained free from recurrence for 4 years.

PROGNOSIS

Based on past experience with this tumor papillary cystadenoma lymphomatosum is considered a benign neoplasm in the Head and Neck Clinic at the Memorial Hospital. The tumor has never recurred following local excision in our clinic. We have found no suggestion of malignant transformation in any excised specimen even after repeated incomplete surgical excisions. No conclusive instance of a malignant Warthin's tumor has been reported in our literature.

END-RESULTS

With one exception (Case 7) all of our patients have been seen at regular intervals—the follow up periods varying from 6 months to 12 years from the date of admission. Six cases have been followed for 5 years or more, and 6 cases have been followed from 3 to 5 years. One patient died of coronary thrombosis 5 years following excision of a cystadenoma lymphomatosum and another succumbed to gastric cancer 30 months after operation for this specific salivary gland tumor. In Case 8 the patient also had reticulum cell lymphosarcoma of the neck and mediastinum; this associated neoplastic disease has been controlled satisfactorily with high voltage roentgen therapy for a period of 5 years.

SUMMARY

Twenty two cases of papillary cystadenoma lymphomatosum of the parotid salivary gland are reported and analyzed. The histogenesis of the tumor has not been definitely established. There is a reasonable anatomic basis to support the theory of its origin from heterotopic salivary gland rests situated in lymph nodes adjacent to or within the parotid gland.

The neoplasm is a distinct morphologic entity but it cannot be distinguished clinically from the relatively common mixed parotid tumor. Cystadenoma lymphomatosum recurs promptly if surgical excision is not complete. All tumors in this series were automatically and clinically benign. There are no satisfactory data to indicate whether these tumors are radiosensitive or radiocurable.

Since the conclusion of this study 3 additional patients with cystadenoma lymphomatosum of the parotid gland

COLOR MATCHING OF SKIN GRAFTS AND FLAPS WITH PERMANENT PIGMENT INJECTION

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TEN years ago Dr. Vilray P. Blair suggested to us the idea of coloring skin grafts so they would match the surrounding tissues. This suggestion and his constant encouragement are responsible for the results we have obtained.

Of necessity free skin grafts and pedicle flaps are often employed about the face to reconstruct features (Fig. 1) replace surface lesions (Fig. 2) or relieve distortion resulting from scar (Fig. 6). Full thickness skin grafts from behind the ear or forehead flaps usually result in reasonably good color matches with face skin but with grafts and flaps from other areas there is often a color contrast that detracts from an otherwise good result. Thus transplanted skin may be lighter or darker than that of the recipient area and may more strikingly lack the red tones of the face skin. Women may use makeup to hide such contrasts but men often refuse to use it.

This problem of contrasting color can be largely overcome by introduction of permanent pigments into the transplanted skin to create a color match with the recipient area.

There is archaeological evidence to show that tattooing of the skin dates as far back as 4000 to 3000 B.C. at which time it was practiced in Egypt. The first records of this practice in Southern China date 1100 B.C. Through the ages there have been various reasons for marking the skin. The Greeks and Romans used this method to mark prisoners of war, criminals, and slaves. It is practiced now for personal adornment and to establish religious, family or tribal markings. Some modern work has been reported on the tattooing of disfiguring white corneal scars; the method has had limited use in making dark skin blemishes less noticeable by injecting lighter colors.

From the Department of Surgery, Washington University School of Medicine, Saint Louis, Missouri.
"Surgery of the Eye," by M. Wessner and B. Y. Alvis, Philadelphia, W. B. Saunders Co. 1930.

On the basis of the cautious use of the procedure over 8 years of time, it is felt that worthwhile results can be obtained with transplanted skin to heighten the perfection of surgical repairs.

Tattooing is the practice of pricking the skin with needles and carrying into the skin and depositing various pigments. Such pigments should be nonpoisonous, stable to light, non-irritating to the skin, and stable to the prolonged effect of tissue metabolism. Extreme insolubility is thus essential. Among the pigments used are the following:

1. White — Barium sulphate is extremely insoluble. It is used in color blending in most instances.

2. Yellows and browns — These come from the ochers, the earthy metallic oxides, and vary in shades from light yellow to brown and red. The color is controlled by the amounts of hematite and limonite present. The shades are controlled by the material mixed with this; these materials are clay, chalk, or gypsum. Artificial ochers, yellow and brown, are produced in probably a more pure state by precipitation of iron salts. The artificial red ochers are produced by roasting the natural yellow and brown ochers, causing them to lose water and be converted into iron oxides. This produces light red, burnt ochre and a yellowish red shade. Umber, a brown ochre, owes its color to the presence of manganese.

3. Black — This is carbon. It is used considerably in color blending.

4. Red — In addition to certain of the ochers alizarin, synthetic or from madder, is used.

TECHNIQUE

The area is prepared with soap and water and alcohol. It must be free from infection. The instruments are sterilized; the pigments may be autoclaved each time or kept as a sterile stock supply.



Fig. 3. a, left, Massive repair of face, lip, and orbit with flap from the chest for defect resulting from an explosion. Color differential and absence of vermilion are very marked. b, Color injection to stimulate vermilion, and match color of cheek. There is still some swelling and peeling of the skin present.



Fig. 4. a, left, Destruction of vermilion of upper and border of lower lip from lye burn. An arm flap repair of border of lower lip has been done. The lining of the lower lip is entirely constructed with arm flap, that of the upper lip with free skin graft. When lipstick is smeared the absence of underlying color is doubly obvious. b, Simulation of both upper and lower vermilion by pigment injection.

The skin appears pale immediately after the injection. This is followed by a period of inflammation lasting a week or 10 days. Following this, there is peeling of the skin (Fig. 3). During the period of inflammation vaseline or sulfathiazole ointment is applied.

The color gradually diffuses and pales somewhat (Figs. 1 and 2). Patchy areas may appear. A second treatment is often needed, at which time color discrepancies can be corrected and patchy areas blended.

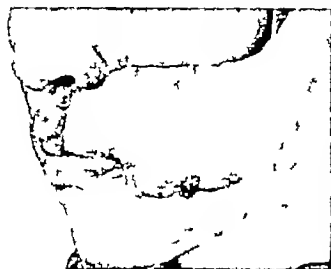
CHOICE OF CASES

Hard scarring interferes with the process of insertion and distribution of the pigment. Areas of no pigmentation or soft white scars are amenable. In such scarred areas the skin is not normal thin scar epithelium being pres-

ent, the derma thin or absent. Here the pigment must be inserted deeper in relation to the skin than in more normal situations.

Skin grafts. It is desirable that the graft be old enough to have achieved the greater part of its relaxation and resemble normal skin as nearly as possible. The graft which is dead white is ideal (Fig. 2). Yellowish and brownish tints to the graft are not serious drawbacks if this is considered in the blending of the pigments for injection. Occasionally a deeply pigmented brown or greenish-brown graft is seen sometimes when the patient has subjected it to sunlight in an effort to improve its color. It is difficult to lighten the color of such an area by pigment injection.

Skin flaps. These are more commonly used in the reconstruction of a feature such as the

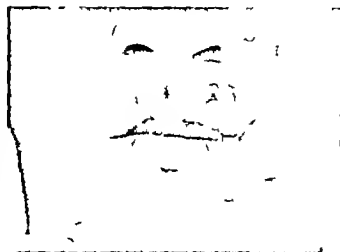


5a



5b

Fig 5 a, Forehead flap in place to reconstruct one third of the full thickness of the upper lip and a portion of the cheek. The absence of vermillion makes the repair look very artificial. b, Completion of the repair with vermillion simulated by pigment injection. This patient has a very dark complexion, and the forehead flap did not match the surrounding tissues as well as usual. c, Final result 6 months after color injection into the flap. The absence of beard was camouflaged by stippling with a brown-black mixture. The simulated vermillion is indistinguishable from the normal except on close examination.



5c

nose, ear or full thickness of the lip or cheek (Figs 1 and 5). The color is more likely to be dead white or yellowish than too dark. The texture is better and there is less superficial

scarring than in the free graft and pigment injection may be done more easily.

Vermillion of the lip. Regardless of the perfection of contour of a lip reconstruction with



Fig 6 a, left, Skin grafts of lower eyelids and nose much lighter in color than surrounding skin. Outer portion of eyebrows missing. b, Three months after matching of grafts

to surrounding skin by pigment injection and simulation of brows by similar process. Because of diffusion of pigments stippling may be too coarse to simulate individual hairs.

out a vermillion the result is very imperfect (Figs. 3, 4 and 5). Lipstick is not entirely adequate because if smeared the underlying absence of vermillion is quite noticeable. Color injection of the border of such a flap reconstruction can reproduce the appearance of the normal vermillion very accurately and adds considerably to the adequacy of the repair. Surgical methods are often inadequate for this portion of the repair.

Bald spots within bearded areas are noticeable but stippling with black has not been an entirely satisfactory disguise (Fig. 5). Black pigment is likely to appear bluish under the skin and must be used with care. Because of the diffusion of pigments the stippling is likely

to be too coarse to simulate individual hairs and may produce a dirty appearance. Bald areas in the eyebrow may be disguised fairly well (Fig. 6).

CONCLUSIONS

Over a period of 8 years the injection of pigment into the skin has been used in 27 instances to match the color of free skin grafts to surrounding facial skin. This method has been used 8 times for the same purpose on skin flaps. It has been used in 10 instances to simulate missing vermillion of the lip. The appearance of the surgical repair has been definitely improved in every case, sometimes markedly so. There have been no complications or bad results from the procedure.

A TECHNIQUE OF ASEPTIC OR CLOSED GASTRIC RESECTION USING THE FURNISS CLAMP

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IT is safe to say that more progress has been made in the reduction of mortality following resection of the stomach during the past 5 years than had been accomplished during the previous 25 or 30 years. This improvement has been brought about largely by three outstanding contributions.

First it has been shown how the starved and debilitated patient can be prepared so that he may be operated upon with relative safety.

Second the widespread preparation of blood plasma both by manufacturing chemists and by hospital laboratories and the improved methods of blood matching for transfusions have made such supportive measures more generally available and safer for use during the operation.

Third the development of the closed or aseptic type of resection.

MORTALITY

Peritonitis pneumonia, operative shock are the main causes of mortality following gastric resection. Pneumonia and shock can be almost completely controlled by adequate preoperative preparation of the patient and by proper supportive measures during operation. The work of Whipple Ravdin and more recently of Varco has made us protein conscious. They have shown us that the starved and debilitated patient can be put into improved condition by the use of a high protein high carbohydrate low fat diet given either orally or by continuous drip through a nasogastric tube. This diet should be supplemented when necessary by intravenous glucose amino acids plasma or blood. Often 1 2 or 3 weeks are necessary to accomplish this—the length of time depending upon the amount of weight lost by the patient. With this preparation these patients if supported during operation by intravenous plasma are able to stand a

long 3 to 4 hour procedure without blood pressure fluctuations and without developing shock.

Where there is no shock, there is rarely pneumonia. Other measures such as guarding against inspiration of stomach contents into the lungs during operation postoperative suction of mucus from the trachea, high Trendelenburg position after operation and care in the administration of fluids to the aged patient are important factors in the prevention of pneumonia. The postoperative encouragement of deep breathing the practice of forceful coughing the elimination of tight adhesive strapping and caution in the postoperative use of morphine which abolishes the cough reflex are measures which prevent the occurrence of atelectasis and so also cut down the incidence of pneumonia.

PERITONITIS THE GREATEST DANGER OF RESECTION

The prevention of peritonitis has been a challenge to surgeons since the beginning of gastric surgery. The percentage of deaths from peritonitis following resection for carcinoma of the stomach has been so great that it stands out vividly on the records of modern surgery. Little progress has been made in this fight until the advent of the aseptic closed resection.

The general mortality following resection of stomach for carcinoma has been all too high. According to Livingston and Pack this runs up to 50 per cent with an average of about 23 per cent. Few realize what a large percentage of these deaths is due to peritonitis. Walters, Priestley and Gray (19) in their book *Carcinoma and Other Malignant Diseases of the Stomach* report that at the Mayo Clinic between the years of 1908-1938 2 772 resections for carcinoma of the stomach were done. They report a general mortality of 16.2 per cent. Of the 450 deaths in this series 368 were au

Read before the Minneapolis Surgical Society April 1943.

topied. Forty two and two tenths per cent of those on whom postmortem examinations were made peritonitis was given as a cause of death, pneumonia 31.3 per cent. At the Mayo Clinic in the 5 year period between the years 1938-1942 inclusive, Gray states that of 596 resections for carcinoma 61 deaths occurred—a mortality of 10.2 per cent. Of these 61 deaths 28 or 45.8 per cent died of peritonitis and 39.6 per cent died from pneumonia. Friedrich and Weber reported 207 resections for carcinoma of the stomach from the surgical clinic at the University in Vienna. They showed a general mortality of 25.1 per cent. In 71 per cent of these cases peritonitis was given as a cause of death. Parsons and Welch reporting a series of 100 resections for carcinoma of the stomach at Massachusetts General Hospital had a general mortality of 35 per cent between the years 1922 and 1936. Their report shows that 33.3 per cent were due to peritonitis, and another 33.3 per cent were due to pneumonia. Boyce reported 91 resections for carcinoma at Charity Hospital, New Orleans, with a general mortality of 56 per cent. Of these deaths, 31.3 per cent were due to peritonitis. In our own experience at Veterans Hospital in Minneapolis in a group of 193 patients admitted for carcinoma of the stomach we explored 90 and resected 36 by the open method. We had 6 deaths, a mortality of 16.6 per cent. Of the 6 who died 3 or 50 per cent died of peritonitis.

This high incidence of peritonitis is understandable when we find that studies made by Seley and Colp show that 93 per cent of cultures taken from patients with carcinoma of the stomach are positive.

Following resection for ulcer peritonitis has never been greatly feared nevertheless when we look into the mortality reports, we find that it actually is of considerable moment. Allen and Welch reporting 151 resections for duodenal ulcer at Massachusetts General Hospital, had a mortality of 9.2 per cent. Four out of 14 deaths, or 28.6 per cent were due to peritonitis. Hinton of New York in reporting a series of 102 resections for ulcer had 5 deaths. Four of these 5 or 80 per cent were due to peritonitis. Walters⁽¹⁸⁾ reporting on surgery of the stomach and duodenum at the

Mayo Clinic for 1941 in 215 resections for duodenal ulcer gave 6 deaths. Four of these or 66.3 per cent were due to peritonitis. In our experience at the Veterans Hospital in Minneapolis we have done 100 gastric resections for ulcer by the open method. In this series we have had 8 deaths, a mortality of 8 per cent. One of these, or 12.5 per cent died of peritonitis. What percentage of peritonitis in these statistics is due to contamination at the time of surgery and what is due to post-operative leakage from suture lines cannot be determined. Seley and Colp have shown that 83 per cent of gastric ulcers and 36.6 per cent of duodenal ulcers show positive cultures of the stomach contents.

These figures I am sure will convince the most skeptical that patients with resections frequently die of peritonitis. The extremely high mortality from peritonitis that has followed resection for carcinoma of the stomach has convinced me that the surgeon using the usual open method is not giving his patient all the protection he is entitled to.

PROTECTION AGAINST PERITONITIS

In our fight against peritonitis we now have available the aseptic or closed method of gastric resection. This method has been in use a comparatively short time and indications are that it is likely to do much toward eliminating this dread complication. Wangenstein (22) has done approximately 150 aseptic resections for carcinoma and 400 resections for ulcer. Following resection for carcinoma he has had 1 death from peritonitis. This was a patient in whom a sponge was left at time of operation. Following resections for ulcer he has had 2 deaths from peritonitis. One of these was due to a leak from a suture line and the other to a subdiaphragmatic abscess. Holman (10) reports 65 aseptic resections for ulcer and carcinoma with 1 death from peritonitis. Babcock reported 35 aseptic resections with no peritonitis. We have done 55 aseptic gastric resections for carcinoma and ulcer with no deaths from peritonitis. While this series is comparatively small it would appear that further reports will indicate we have indeed a powerful weapon against the greatest danger of gastric resection. Since postoperative leak

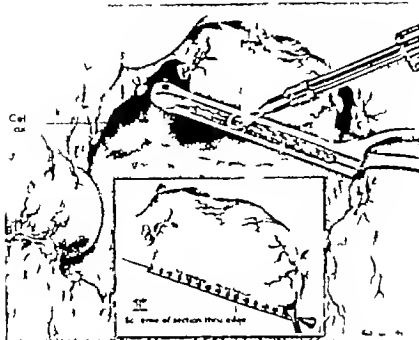


Fig. 2. Mucosa of cuff is first scraped out. The remnant is then thoroughly seared with actual cautery until it assumes leathery appearance. Inset shows needle pushed through serrated edge and clamp is then removed.

aseptic surgery of the bowel. We became interested in it because it appeared to give a better control of hemorrhage than any other means previously used. With it one can cauterize individually with coagulating diathermy any artery that has not already been controlled by the electric actual cautery and the crushing effect of the clamp itself. With this technique the clamp is removed prior to inversion of the cauterized edges into the stomach cavity. With the clamp off and the needle having been thrust through the serrated edges to maintain closure of the cut-off viscus, inspection of the cut edges of the stomach and bowel is made possible. Any bleeding artery can then be coagulated with diathermy point or, if one desires, can be ligated. In our experience bleeders occur frequently in spite of thorough electrocauterization.

The method lives up to the three cardinal points of an aseptic technique—thorough crushing of stomach wall, the production of a narrow margin of inverted edge and adequate control of hemorrhage.

In selecting a clamp for performing an aseptic anastomosis one must consider two points. First the crushing surface must not be too wide for the tissue that is crushed must be inverted into the lumen of bowel. Too much inverted cuff at the angles of the anastomosis is a common cause of obstruction of the distal outlet. The second point is that the clamp should be strong enough to crush tissues forcibly. This is helpful in hemostasis. The serrated crushing surface of the Furness clamp is approximately 0.5 centimeter wide. There is a screw fulcrum at the end of the handle to cause forcible pressure. Down the face of each blade is a groove approximately one half the pitch of the teeth. This groove forms a channel through which a long needle may be thrust when the jaws are approximated. This maintains closure of the viscus after the clamp is removed.

ANTERIOR OR POSTERIOR ANASTOMOSIS?

Throughout the literature of gastric resection the argument frequently arises—should

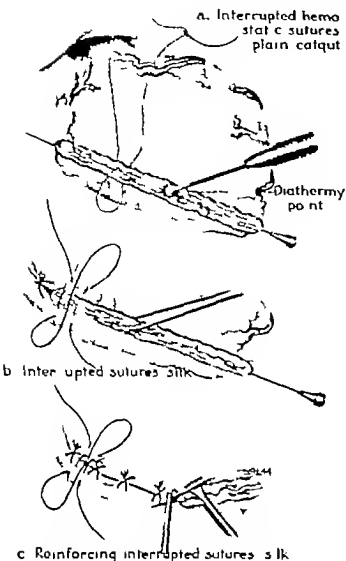


Fig. 3. a, Interrupted plain mattress sutures and hemostats in Hofmeister portion. Diathermy point coagulates a bleeder. b, Closure of Hofmeister portion is begun, interrupted double Lembert silk sutures being used. c, Furniss needle is pulled down to site of anastomosis and Hofmeister closure is then reinforced with many more silk sutures.

one make the anastomosis posterior or anterior to the colon. Both methods have their staunch and ardent supporters.

We have done posterior anastomoses for some time and for good reasons. We feel that a quick emptying stomach is an essential of a good gastric resection. Fast emptying means quick discharge of acid from the stomach and in ulcer this is what is desired. I am convinced that a well made posterior anastomosis functions better than an anterior—especially the no-loop anterior as recommended by Lord Moynihan which approximates the distal loop to the lesser curvature. He had two obstruc-

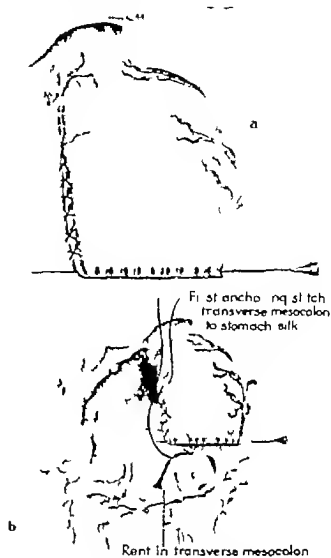


Fig. 4. a, Hofmeister portion has been thoroughly closed with single row of silk sutures and stomach is ready for anastomosis to jejunum. b, First anchoring stitch joining stomach to transverse mesocolon is now conveniently placed. When tied later it will accomplish a rotation of lesser curvature to posterior aspect of rent in mesocolon.

tions in anterior anastomosis when he was doing the reverse method and attaching the proximal loop to the lesser curvature. We had a similar experience with 2 cases in anterior anastomosis in which we attached the proximal loop to the lesser curvature. These patients both developed obstruction of the proximal loop about 3 weeks after operation necessitating reoperation. One recovered and one died of gangrene of the proximal jejunal loop and duodenum.

I am convinced that the reason many surgeons are having trouble with posterior anastomoses is because they are still using the

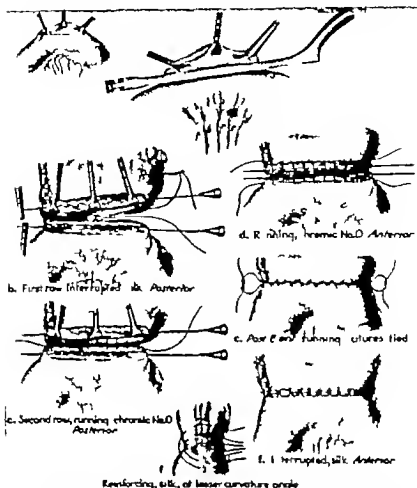


Fig. 5. A. Farness clamp is placed on side of jejunum and triangular bite is removed. B. Actual anastomosis. C. Steps in suturing of anastomosis. Note that posterior row of silk sutures are so placed as to bring knots on the outside of anastomosis. F. Angle of lesser curvature is carefully protected with three interrupted silk sutures.

Pólya type of anastomosis. When this is done especially in high resection the process of bringing the anastomosis comfortably and safely below the attachment of the mesocolon onto the stomach is very often difficult and hazardous. If on the other hand, one uses the Hofmeister technique the placement of the anastomosis well below the mesocolon so that this cannot impinge upon or interfere with the functioning of the stoma, is usually a simple matter. The Hofmeister technique transforms a short, stubby stomach into a long thin tubular one thus making a posterior anastomosis easy.

With the occasional difficult case in an obese person or in an unusually high resection, one should give some thought to the place where he makes the opening in the mesocolon. With the Hofmeister technique this opening need not be large—not over 2 to 2.5 inches in diameter. If one makes it posteriorly near the pancreas in the difficult case, he is making it hard for himself. For then he has only the length of the stomach to utilize in getting it below the mesocolon. On the other hand if he makes the opening anteriorly near the colon he has the width of mesocolon between the opening and the pancreas which

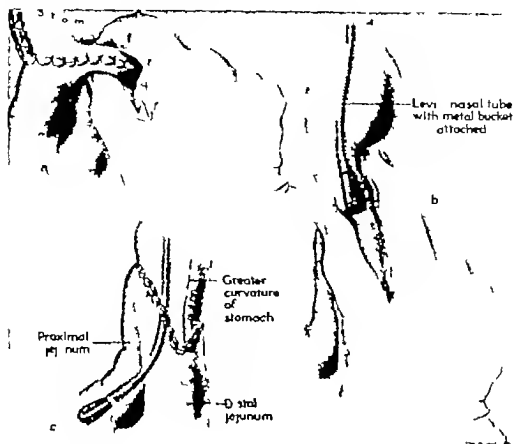


Fig. 6 a. Anastomosis is broken down particularly at inlet and outlet. b and c. Levin tube with metal bucket attached is grasped through wall of stomach and passed through anastomosis into proximal loop of jejunum.

structure is movable and available for making the attachment onto the stomach easier

Moreover we feel that in the extremely high resection in a fat person in whom there is difficulty in getting the anastomosis below the mesocolon even when the Hofmeister technique is used we would rather allow the two loops of bowel to run freely through the slit in the mesocolon and to attach the edge of this to the loops of bowel doing this in such a way as to separate the loops one from the other. We prefer this to doing an anterior anastomosis.

There are other reasons why we are committed to a posterior anastomosis. In the first place it allows for making the anastomosis close to the duodenal jejunal junction. The jejunum is largest at this point which makes for better stoma with less danger of puckering and obstruction of the outlets. Moreover Wangensteen (23) reminding us of our physiology calls our attention to the fact that the

best hormonal stimulus for elaboration of pancreatic juice is secretin acting on the pancreas through the blood stream. Secretin is elaborated in the duodenal mucosa by contact stimulation of hydrochloric acid. Therefore in resection for ulcer an anastomosis made near the duodenum allows hydrochloric acid to bathe the duodenal wall thus stimulating the formation of pancreatic juice which in turn will produce neutralization of the acid (Fig 10).

Experimentally it seems to have been shown that the farther down the bowel an anastomosis is made the less resistant the mucosa is to hydrochloric acid. This now appears to be borne out clinically. Kiefer reporting 173 gastric resections for duodenal ulcer done at the Lahey Clinic, at the recent meeting of the American Medical Association reviewed 20 cases that subsequently developed gastro-jejunal ulcer or hemorrhages. Sixteen of these operations were done by the anterior

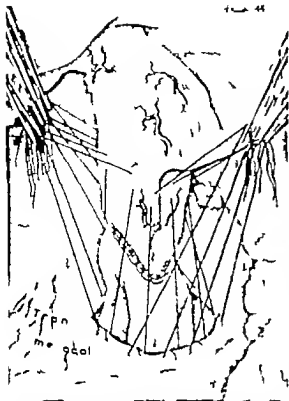


Fig. 7. Remainder of silk anchoring sutures are now placed. These are tied from above, after anastomosis has been pulled through rest in mesocolon. These are so placed as to accomplish rotation of stomach, thus making lesser curvature posterior and greater curvature anterior.

method which means an anastomosis well down on the jejunum. Three resections in which a posterior anastomosis was used were all by the Finsterer exclusion method, leaving the antrum of the stomach. Whenever this has been done there usually is a high incidence of gastrojejunal ulcer. In 1 case it was not stated whether operation was anterior or posterior. Wangensteen (22) on the other hand using the posterior no-loop or short loop anastomosis, has reported approximately 350 carefully followed resections without a single gastrojejunal ulcer. As both Kiefer and Wangensteen report using high resections it would seem that the outstanding difference between the two series is the use of the anterior long loop anastomosis on the one hand, and the posterior short or no-loop method on the other.

MECHANICS OF A SATISFACTORY POSTERIOR ANASTOMOSIS

I would like here to discuss briefly the mechanics of what I consider a satisfactory well functioning posterior anastomosis applicable to either the open or the closed method.

The first essential is the use of the Hofmeister procedure. This is basic in the production of an easy comfortable posterior anastomosis and there is nothing that will do more toward the elimination of kinks and tension. The next point to consider is the relative size of the openings in the stomach and jejunum. In this respect we are careful to make the opening in the jejunum somewhat smaller than the opening in the end of the stomach. This is accomplished by putting the side of the jejunum on a stretch prior to application of clamp. Then if we apply the clamp so that the apparent lengths of the openings are the same the actual opening in the jejunum will be somewhat smaller than the opening of the stomach. This obviates the possibility of puckering that occasionally occurs at the outlets when the converse happens, and the opening in the jejunum is made larger than the end of the stomach.

There is another point that is important in placing the clamp on the jejunum. Instead of taking a straight tangential bite off the edge of the bowel, one should take a triangular bite, wider in its central portion than at its edges. When these two things are done, namely stretching the bowel prior to setting the clamp and taking a triangular bite off the jejunum when the anastomosis is made we accomplish a pantaloons effect on the two limbs of the jejunum. This makes for a more vertical mode of entry and exit, and as a result better functioning of the stoma.

THE PREVENTION OF KINKING OF PROXIMAL LOOP AT INLET OF ANASTOMOSIS

The next thing to consider is the length of jejunal loop to be used in a posterior anastomosis, and the optimal direction of the gastrojejunal anastomosis. We have been using a short loop anastomosis, making it about 2 to 3 inches from the ligament of Treitz—allowing only enough room to perform an end-to-end anastomosis in the event of the formation of a

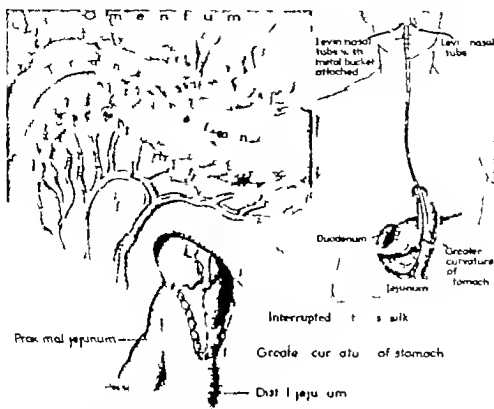


Fig. 8 Anastomosis is brought below mesocolon and sutures are tied from above. These are placed as high above line of anastomosis as possible. Inset shows second nasal tube passed into stomach on patient's return to room.

gastrojejunal ulcer at a future date. This short loop allows hydrochloric acid from the stomach to bathe the duodenal mucosa, and thus stimulate the formation of secretin (Fig. 10). In order to accomplish a safe short loop anastomosis, one should anchor the end of the stomach so that it will be held in such a direction as to make possible a comfortable no link stoma. To do this we utilize the attachments of the rent in the mesocolon onto the wall of the stomach to control the direction of the stomach as it joins onto the jejunum. Obviously our gastrojejunostomy in a posterior type of resection would be less prone to become kinked if the lesser and greater curvatures of the stomach instead of lying in a transverse direction as they normally do were to lie in a sagittal direction with the lesser curvature posterior and the greater curvature anterior. If that were the case the cut end of the stomach would apply itself comfortably to the jejunum allowing this bowel to lie in a more natural direction as it comes forward from the ligament of Treitz. When this is not done, and the stomach is left

to lie in its customary transverse direction it is necessary for the jejunum to turn over first to the right and then at its junction with the lesser curvature end of the stomach make a sharp turn back to the left. No harm is done by rotation of the stomach but much damage may be done if the jejunum becomes kinked.

This optimum direction of the stomach can be brought about by judicious placement of sutures when suturing the edge of the opening in the mesocolon to the stomach. To accomplish this the first stitch joining the stomach to the mesocolon approximates the lesser curvature of the stomach to a point in the slit in the mesocolon directly above the place where the jejunum emerges from the ligament of Treitz, or even slightly to the left of this point. A silk suture is used for this purpose (Fig. 4 b). What this does is to rotate the lesser curvature posteriorly and to the left. The greater curvature conversely rotates anteriorly and to the right. Several more silk sutures are placed about the margin of the slit strengthening the first stitch and maintaining the desired anteroposterior direction of the

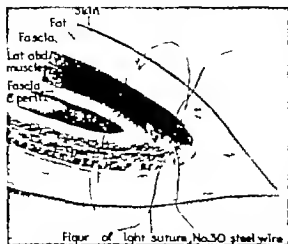


Fig. 9. Abdominal wall closed with interrupted figure-eight H-gal steel wire sutures.

greater and lesser curvatures at a point directly above the ligament of Treitz. The attachment of mesocolon onto the stomach is made as far above the anastomosis as is possible.

THE DUMPING STOMACH

These improvements in the mechanics of a posterior anastomosis—the pantaloons effect produced in the loops of jejunum the rotation of the stomach so that it lies in a sagittal or anteroposterior plane instead of its normal coronal or frontal plane and held there by sutures to the opening in the mesocolon the attachment of the mesocolon to the stomach high above the line of anastomosis—all tend to promote a free, well functioning stoma and a quick emptying stomach. This is desirable in any resection but is particularly important in patients with ulcer. There any stasis of gastric secretion is bad. The quicker it is discharged from the stomach and neutralized by alkaline juices, the better. While much has been written about the dumping stomach, this is not a particularly objectionable thing. It is true that these patients may complain of some distress following the too rapid ingestion of fluids. However if they are cautioned to avoid drinking too much fluid with their meals and to eat six times a day instead of three for the first few months following surgery they usually get along very well. The

small bowel tends to adjust itself rapidly to the new conditions and after a time these patients have little distress.

METHOD OF PASSING LEVIN NASAL TUBE INTO PROXIMAL LOOP WITHOUT BREAKING ASEPTIC TECHNIQUE

Preliminary to placing patient on the operating table, a nasogastric tube is passed into the stomach. An ordinary No. 14 Levin tube is used. To the end of this is attached a metal bucket—one that we have taken off of a double lumen Abbott Rawson tube. The use of this particular type of bucket has been advantageous because of the fact that this bucket gradually widens toward the distal end, a feature which facilitates palpation and allows one to grasp and manipulate it through the stomach wall easier than one could the usual olive-shaped bucket as is used for example on the Rehfuss tube. This tube serves a dual purpose. Suction on it keeps the stomach in an empty collapsed state during operation—a most important consideration in doing an aseptic resection and, second, the bucket on the end can be palpated through the wall of the stomach so that at the completion of the anastomosis the tube can be milked down through the stoma into the proximal loop. The duodenum and jejunum are thus kept collapsed during the postoperative period. McClure and Fallis, in 74 resections, had 4 deaths. Three of these were due to obstruction of the proximal loop with subsequent perforation. These probably would not have occurred if a suction tube had been used in the proximal jejunum to decompress this loop of bowel. There should be no duodenal blow-outs if pressure is eliminated from this viscus.

Tying a metallic bucket on the end of the tube makes it possible to place it in the proximal loop without the necessity of opening the anastomosis and thus breaking the aseptic technique. In passing the tube before patient is placed on the table, the blunt tip is first cut off. The tube is fed through the nose, grasped with a forceps as it comes into the throat, and pulled out through the mouth. The bucket is then tied into the tip with silk and the tube swallowed easily. If the metal bucket is already fastened to the nasal tube, a small



Fig. 10. Roentgenograms taken of stomach before and after resection for ulcer. Picture on right taken immediately after ingestion of barium shows a fast emptying stomach. Arrow points to barium that has gone into proximal duodenojejunal loop. This shows that with a posterior short loop anastomosis hydrochloric acid can bathe the duodenal wall and thus stimulate the formation of secretin.

catheter may be passed through the nose, pulled out through the mouth and tied into the open end of the nasal tube. The nasal tube is then pulled back through the nose in a retrograde manner and the bucket can then be swallowed easily.

There are two methods of keeping both the proximal jejunal loop and the stomach collapsed during the convalescent period. One can use a single nine hole Levin tube and attach the metallic bucket to that. This has sufficient holes to keep both the jejunum and stomach collapsed provided the tube does not become obstructed. We have felt so strongly regarding the necessity of keeping the pressure off both of these organs that we have not been content with using a single tube. Too often a single tube becomes blocked by a plug of mucus that cannot be washed out. Therefore we have been using two nasal tubes, each a No. 14 Levin tube of the usual three hole variety. The first has the metallic bucket attached and is placed through the stoma into the proximal jejunal loop during this operation. The second terminates in the stomach and is inserted either before the patient is taken into the operating room or on return to his room (Fig. 8 insert). These tubes are attached to separate suction bottles. After

bile starts to come from the tube terminating in the stomach, one can be fairly certain that the inlet of the stoma is functioning. Soon after that occurs the tube in the jejunum can usually be removed with safety. Patients seem to tolerate two nasal tubes almost as comfortably as one.

ANESTHESIA

For anesthesia we have used spinal almost routinely. This allows the use of cautery and diathermy in the operating room without danger. For the last year we have been using continuous spinal as recommended by Lemon. We have found that intravenous morphine in small doses has been a helpful adjunct to this. This method has been a great aid in carrying the gastric case through a long operation. During the years that we have used the one dose spinal anesthetic we tried in turn novocain, metycaine and pontocaine reinforced with novocain splanchnic block. None of these has been completely satisfactory. With all of them there is an initial let-down often with a distressing drop in blood pressure. There is also the feeling on the surgeon's part that he must hurry to get through before the anesthesia wears off. With continuous spinal the initial blood pressure drop is usually

minimal, and the subsequent small additional doses allow one to take as much time as is necessary for good surgery.

The anesthetic of choice for gastric resection at the University of Minnesota Hospitals now is cyclopropane given by the closed method and supplemented by curare for relaxation.

THE OPERATION

For more than 2 years we have used the oblique, left subcostal incision transecting the rectus muscle. This incision affords a splendid exposure of the stomach and duodenum and closes readily. We almost routinely make our anastomosis between the stomach and jejunum before closing the duodenal stump. We began doing this when we were using the one dose spinal anesthesia and wished to do this part of the operation while the relaxation was at its height. Moreover if for any reason a hurried termination of the operation were necessary, we believed that it was best to have this most essential phase of the operation completed. After we had used this method a few times we found that it was easier to mobilize the duodenum after having the stomach transected, free, and under control.

In resection for carcinoma all possible gland bearing gastrohepatic and gastrocolic mesentery should be taken with the specimen. The lesser curvature is mobilized well up toward the esophagus, and the left gastric artery is tied doubly with chromic catgut or heavy silk. The greater curvature is liberated up to the short gastric arteries. One or more of these may be tied, care being taken to leave enough blood supply to maintain the circulation of the stomach which may now be entirely dependent on this source. The stomach wall should be completely denuded of mesentery, and fat for about $\frac{1}{4}$ inch above the line where the Furniss clamp is to be placed. Intervening fat and alveolar tissues interfere with strong union between stomach and bowel.

The Furniss clamp with handles curved upward is then applied obliquely across the stomach. It is screwed tightly into place crushing the stomach wall firmly. A Payr clamp is applied about $\frac{1}{4}$ inch distal to the Furniss clamp and the stomach is cut across with the electrocautery knife (Fig. 1).

CAUTERIZATION OF CUFF AND HEMOSTASIS

A short cuff of stomach wall is always left to protrude beyond the Furniss clamp. This is an important point in hemostasis as emphasized by Gerbode. The first step in the cauterization of this cuff consists in scraping out the mucous membrane portion. This reduces the volume of the cuff to be inverted. The remainder is then thoroughly cooked with the actual cautery (Fig. 2). As we depend on this chiefly to control bleeding, we spend considerable time in thoroughly searing it. When complete the cuff presents a cooked, leathery appearance. The cautery is applied only to the cuff and *must not touch the clamp*. If that is done very little heat is transmitted through the clamp to the wall of the stomach. At the greater curvature end, the volume of cuff is reduced to a minimum in order to cut down on the amount to be inverted at this point which is to be the outlet of the stoma.

The long Furniss needle is now pushed through the clamp sealing off the cut, serrated end of the stomach. The clamp is removed and we depend on the needle to maintain closure (Fig. 2 insert). The protruding end of the needle should be cleansed with an antiseptic. With the clamp off any bleeders that the cautery has not controlled will soon bleed. These are then coagulated individually with the coagulating diathermy point (Fig. 3 a). This feature of the Furniss clamp which allows for its removal prior to the inversion of the cauterized edges gives one considerable assurance as to hemostasis.

At this point, as an additional aid in the control of bleeding, four or five through-and-through sutures of plain catgut are placed at close intervals along the upper or Hofmeister portion of the anastomosis. These sutures are put in just under the Furniss needle (Fig. 3 a).

THE HOFMEISTER PART OF TECHNIQUE

It was only after numerous trials of different methods that we were able to accomplish a satisfactory Hofmeister technique using the Furniss clamp and needle. This problem was finally solved by the simple expedient of partial pulling out of the needle as described in the following.

After placement of the hemostatic sutures, the closure of the upper part, or Hofmeister portion of the stomach is begun. This is started high on the lesser curvature burying the needle and the canterized edges of stomach into the wall by interrupted double Lambert sutures (Fig 3 b). The Furniss needle is easily depressed toward the gastric lumen and the edges of the stomach wall to be sutured readily roll into opposition. These at first are placed not too close together—about $\frac{1}{4}$ inch apart. These sutures are continued until all of the canterized edge of the stomach is covered except that portion that is to be used for the anastomosis—a length of about 6 centimeters.

The needle is then extracted down as far as this point still maintaining the site of anastomosis sealed with the needle (Fig 3 c). Lest there be any leakage, an Allis forceps is applied just above the point of emergence of the needle, so that this portion is kept closed until the anastomosis is completed. Any possible contamination of the needle is taken care of by wiping it off with mercresson, or similar antiseptic. Two Allis forceps are then put on the cut end of the stomach and the viscus is pulled down firmly. With the needle out of the portion closed by the Hofmeister method, and having used interrupted sutures, this procedure will bring about considerable lengthening of the remnant of stomach. After the lengthening process is completed the Hofmeister portion of the anastomosis is reinforced with several more interrupted silk stitches placed between the original sutures, thoroughly sealing off this area (Fig 3 c). These stitches take a good bite of serosa and muscularis. A single row of double Lambert silk sutures closely applied is deemed sufficient to seal this portion (Fig 4 a).

THE ANASTOMOSIS

An avascular area is selected to the left of the midline just above the ligament of Treitz and a small opening is made. At this point the first silk suture is placed that will later join the lesser curvature of the stomach to the posterior aspect of the slit in the mesocolon. This suture is merely placed at this time and not tied (Fig 4 b). It is much easier to put it in now than later after the anastomosis is com-

pleted. Care must be taken to place this stitch high in the lesser curvature so that the attachment of mesocolon to the stomach will be well above the line of anastomosis. The jejunum is next brought up through the slit in the mesocolon. An Allis forceps is placed at a point about 2 to 3 inches below the ligament of Treitz marking the proximal end of the anastomosis. A second Allis forceps is placed about 3 centimeters below this point marking the distal end of the anastomosis. A third Allis clamp is placed between the two (Fig 5 a'). One must be careful to place all three of these in the midmesenteric portion of the jejunum. The outer two Allis forceps are then stretched apart. The central Allis forceps is elevated so that when the Furniss clamp is applied and the Furniss needle inserted its central portion will transect the jejunum at about the junction of the inner two-thirds and outer one third of the bowel thus removing a triangular wedge from the side of the jejunum. This is removed with electric cautery again leaving a narrow cuff that is thoroughly seared (Fig 5 a).

The anastomosis is made by joining the proximal jejunum to the lesser curvature, and the distal loop to the greater curvature side of the stomach. The pointed ends of the two Furniss needles are steadied by a small Kocher forceps. We never use the protecting caps that are supplied with the Furniss needles as there is danger of these slipping off and getting lost. An Allis forceps grasps the stomach and jejunum at the greater curvature end to facilitate handling during suturing (Fig 5 b).

The anastomosis is accomplished by two rows of sutures—an outer layer of interrupted silk double Lambert sutures and an inner layer of running chromic No. 0 suture. The outer layer of interrupted sutures is started at the lesser curvature going toward the greater curvature end. These are placed fairly close to the needles allowing only room for the inner row of running chromic suture that is to be placed between outer silk sutures and the area crushed by the clamp. The row of interrupted silk double Lambert sutures are inserted in such a way that the knots will be on the outside of the anastomosis when it is completed (Fig 5 b). When this row is fin-

ished the inner line of running chromic suture is placed. This starts at the greater curvature. These are placed loosely until the entire row is placed. The two ends of running suture are then pulled taut thus bringing the opposing surfaces into snug apposition. The ends of this suture are left loose (Fig 5 c).

A similar running chromic suture is then placed on the anterior aspect of needles, also at first placed loosely (Fig 5 d). After both rows are in the four ends are pulled taut. The Furniss needles are now pulled out entirely. The ends of the posterior row of chromic cat gut are then tied to the ends of the anterior row of chromic suture thus completing one row about the anastomosis (Fig 5 e). A row of interrupted double Lembert silk sutures on the anterior surface completes the anastomosis (Fig 5 f).

The junction between the proximal loop and the lesser curvature must be protected. This is done by attaching the proximal loop over the lower end of the Hofmeister portion with three or four silk sutures. In placing these sutures, a bite is taken first in the anterior surface of the stomach next on the posterior surface and finally a broad bite is taken in the surface of the proximal jejunum. When these are tied the angle is safeguarded (Fig 5 f').

The stoma is now broken down with the thumb and forefinger. Care must be taken that this be done particularly well at the inlet and outlet of the stoma where obstructions are liable to occur (Fig 6 a). Then the bucket attached to the nasal tube is palpated through the wall of the stomach and is milked past the stoma into the proximal loop for a distance of 4 to 5 inches (Fig 6 b and 6 c). The anesthetist can help at this point by pushing in the nasal tube. We consider this a most essential safety measure in the prevention of tension in this loop of bowel. A twist or kink at the inlet of the anastomosis may form a closed loop of obstructed bowel with resultant gangrene or blowout of the duodenum.

Sutures joining the edge of the slit in the mesentery to the wall of the stomach are best put in before the anastomosis is pulled through this opening. We have already placed the first stitch joining the lesser curvature to the posterior aspect of the slit. The remainder

are now inserted placing them in such a way as will bring about a rotation of the stomach, lesser curvature posterior and greater curvature anterior (Fig 7). These sutures, when tied after the anastomosis is pulled through the opening in the mesocolon will hold the stomach in an anteroposterior direction—the optimal direction for good function and the prevention of jejunal kinks (Fig 8).

CLOSURE OF DUODENAL STUMP

In the closure of the duodenal stump one cannot be too careful. We usually use the Furniss clamp or Clute's modification. The stomach and portion of duodenum are removed with cautery the needle inserted and clamp removed. A running chromic suture is used to invert the end of the duodenum. As this is pulled taut, the needle is removed. This suture is tied to itself at each end. A second row of double Lembert silk sutures reinforces the first layer. The stump is next buried into the wall of the pancreas with several silk sutures taken in the capsule of the gland. It is then covered with omentum.

When it is not technically possible to remove the pylorus and duodenal ulcer the lower end of the antrum of the stomach is left. When this is done the antrum mucosa must be removed, otherwise there is a high incidence of gastrojejunal ulcer following resection. This can readily be done by the method of Wangenstein (24). In this technique after dissecting out and closing the mucosal lining without breaking the aseptic technique, the mainstay of the procedure lies in a careful approximation of the submucosal and circular muscle layers of the prepyloric antrum by one or two rows of interrupted Halsted mattress sutures of fine silk. After placing these sutures, the remnants of the antral pouch are cut away leaving only enough tissue to permit easy approximation of the edges *without inversion*.

RESULTS

We have used the Furniss clamp in 46 gastric resections for ulcer. In this series we have had 1 death, a mortality of 2.2 per cent. This death was due to a transfusion or sulfanilamide reaction. This patient became jaun-

died and died of anuria. We have used this technique in 11 resections for carcinoma. Here also we have had 1 death a mortality of 9.9 per cent. This was in a poor risk patient with mitral stenosis. He died of cardiac failure in the fourth postoperative day.

SUMMARY

Pentontitis is the most common cause of death following resection of the stomach for ulcer and especially following resection for carcinoma when the open type of anastomosis is used. During the past 5 years published reports indicate that the aseptic or closed method of gastric resection will do much toward the elimination of pentontitis as a complication.

A method of aseptic gastric resection utilizing the Furniss clamp and needle is described. They lend themselves particularly well to the performance of the Hofmeister type of anastomosis.

A means of improving the mechanics of the posterior type of anastomosis is outlined wherein a rotation of the stomach is brought about so as to prevent obstruction of the proximal loop as it joins the lesser curvature of the stomach.

A method of obtaining a pantaloone effect on the afferent and efferent loops of jejunum is described. In this way better function of the stoma is accomplished.

Details of passing a nasogastric suction tube through the anastomosis into the proximal jejunal loop without breaking the aseptic technique are presented.

As it is possible to remove the Furniss clamp before the cut edges of the stomach and bowel are inverted in toward the lumen of the stomach, this method provides a better control of hemorrhage than any other type of closed gastric resection. Because of that feature any bleeders not controlled by the crushing effect of the clamp and the electrocautery may be coagulated individually by diathermy point or ligated.

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Fig. 2

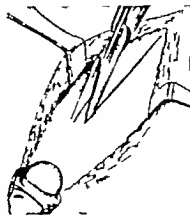


Fig. 3

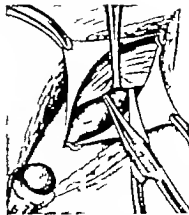


Fig. 4



Fig. 5

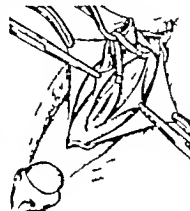


Fig. 6

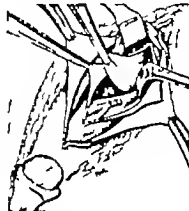


Fig. 7

Fig. 2. Location and extent of inguinal incision—a, internal ring; b, external ring.

Fig. 3. Location of external oblique fascia. External ring is not opened ordinarily.

Fig. 4. Dissection of cremasteric muscle from the internal oblique muscle. The cremasteric muscle is also separated from Poupart's ligament (this is not shown in the drawing).

Fig. 5. Longitudinal incision of cremasteric muscle and infundibuliform fascia exposing dilated internal spermatic vein.

Fig. 6. Internal spermatic vein is doubly ligated above its bifurcation. Vein collapses after proximal ligation. About 5 centimeters of vein is evulsed.

Fig. 7. Areolar tissue in floor of cord is explored and an indirect, incomplete inguinal, hernial sac is exposed.

static column of blood that is responsible for the varicocele and does not impair the collateral venous circulation either in the cord or at the external ring. Low ligation of the internal spermatic veins near the point of origin in the testicle as in the old operation interferes with the collateral circulation in the pampiniform plexus. It is an improper angiologic procedure and may be compared with ligation of the greater saphenous vein at the ankle for cure of varicose veins.

DISCUSSION OF OPERATIONS FOR VARICOCELE

Ivanitschewitch recommends ligation of the spermatic veins in the retroperitoneal space through

a left abdominal incision. Suspension of the testicle with a fascial strip without vein ligation through an inguinal incision as advocated by Londres. Skinner recommends ligation below the external ring and Londres' fascial suspension of testicle. Bertola transplants the internal spermatic veins from the cord to a position beneath the fascia. Bernardi uses an inguinal incision as recommended by Hauta. The external oblique fascia is incised in all of these procedures. None of them correct the associated indirect inguinal hernia, either actual or potential. Failure to do so may be the reason for the persistence of pain even when the varicocele is cured. Since varicocele and



Fig. 8.

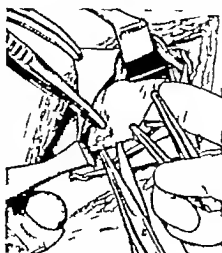


Fig. 9.

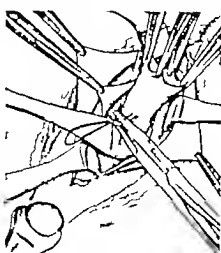


Fig. 10.

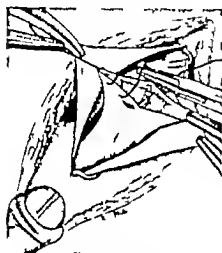


Fig. 11.



Fig. 12.

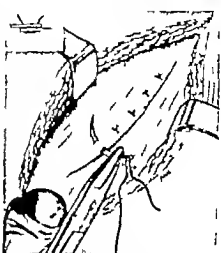


Fig. 13.

Fig. 8. Sac is opened and finger is introduced for investigation of direct inguinal hernia. Note inferior epigastric vessels.

Fig. 9. Prevesical fat is dissected from the sac. Any direct hernia is indirectized. Sac is also separated from vas deferens, inferior epigastric vessels, and cord structures (not shown).

Fig. 10. Ligation of sac with a continuous mattress suture. Stump retracts high above the level of the conjoined tendon (not shown).

Fig. 11. Transverse closure of cremasteric muscle, incorporating distal stump of the internal spermatic vein. This secures some shortening of the cremasteric muscle and produces some suspension of the testicle.

Fig. 12. Suturing the internal oblique muscle over the cord to the shelving edge of Poupart's ligament. This produces an anatomical relationship of these structures as seen in the female.

Fig. 13. Inbrication closure of the external oblique fascia (see insert).

hernia frequently coexist, an operation for the correction of both is the logical procedure when surgical treatment is decided upon.

The combined operation to be described below comprises internal spermatic vein ligation at the internal inguinal ring, ligation of the hernial sac, muscular suspension of the testicle and herniorrhaphy. Ligation at this point (Fig. 1) does not disturb the anastomosis with the remaining portion of the primary system (ductus deferens and external spermatic) nor does it destroy the communication with the secondary system. An adequate venous collateral circulation is maintained

in the epididymis and testicle. Hydrocele has not been observed as a postoperative complication. Likewise, testicular atrophy does not develop because the arterial circulation is not disturbed. Both of these complications are frequent following the old operation through the scrotum. Ligation at the external ring interferes with the collateral circulation to some extent and results are occasionally unsatisfactory, as shown in Table II.

The circumstances leading to the development of the combined operation may be of interest. In the beginning the old operation was performed on several patients. Dissatisfaction with this pro-

TABLE I.—THE ASSOCIATION OF VARICOCELE AND INDIRECT INGUINAL HERNIA

	Number of cases	Number of hernia demonstrated	
		No.	Percent
Group I (ligation of external ring)	4		
Group II (ligation of internal ring, herniorrhaphy)	3	3	
Miscellaneous group	7	5	
Total	45	37	5

cedure led to ligation of the veins at the external inguinal ring, with longitudinal incision of the cremasteric muscle and fascia and transverse closure, in order to suspend the testicle. This type of operation was carried out on 41 patients and they constitute group I, as shown in Tables I and II. Meanwhile, cognizance was taken of the frequent association of varicocele and inguinal hernia. Herniorrhaphy on these patients permitted observation of the static column of blood in the internal spermatic veins causing the varicocele. Finally ligation of the veins was done at the internal inguinal ring which produced a cure of the varicocele and led to the combined operation. It has been performed in 32 patients and they are found in group II. The remaining 72 patients constitute a miscellaneous group most of whom were not operated upon because of lack of symptoms, while others with hernia are awaiting operation. Three patients in this group with varicocele had only a herniorrhaphy performed and the varicocele was unrelieved. These were operated upon before ligation at the internal ring was considered a proper procedure. However their symptoms were relieved.

TECHNIQUE OF THE COMBINED OPERATION

The details in technique in the combined operation are illustrated in Figures 2 to 13. It is performed under intrathecal spinal anesthesia. A left inguinal incision is made and the external oblique fascia is exposed. The inguinal canal is opened to within 2 to 3 centimeters of the external ring and the spermatic cord is separated from the conjoint tendon and Poupart's ligament. It is not otherwise disturbed from its bed in order to avoid unnecessary damage to the collateral circulation. The internal oblique muscle is then retracted upward. A longitudinal incision is made in the anterior portion of the cremasteric muscle and fascia. One large internal spermatic vein and its bifurcating branches are exposed. The other compartments of the cord are not disturbed. The areolar tissue about the internal spermatic vein is dissected with care in order to separate the artery

TABLE II.—FOLLOWUP (3 TO 15 MONTHS) ON PATIENTS HAVING VARICOCELE OPERATION

	Group I		Group II	
	Number followed		Testicle normal	
Testicle normal	8		3	
Testicle atrophied				
Hydrocele				
Testicle not all suspended			3	
Pain not relieved			6	
Varicocele still present				
Hernia inguinal			6	

from the vein. The vein is doubly ligated with No. 1 chromic catgut and silk and about 5 centimeters of intervening vein is excised. The proximal ligation is carried out at the internal ring and the end of the vein is allowed to retract upward. The areolar tissue in the medial floor of the cord is explored for the hernial sac which is then mobilized and opened into. With the forefinger within the sac, exploration for direct hernia is performed. Any direct hernia is indirectized. The prevesical fat is dissected from the sac as is the vas deferens, inferior epigastric vessels, and the cord structures. The sac is ligated with a running mattress suture. After the sac is cut, the stump retracts high above the level of the conjoint tendon. The cremasteric muscle and fascia are then closed transversely so as to secure partial suspension of the testicle. A continuous suture of No. 1 chromic catgut is used for this purpose and the distal end of the vein is included in this suture.

The herniorrhaphy was completed after the technique of Ferguson in the first 20 cases in which the combined operation was done. However in the last 12 patients on whom the combined operation has been performed, a modified type of herniorrhaphy has been used with good results. The internal oblique muscle is sutured to Poupart's ligament producing an anatomical situation observed in the female. Simple imbrication of the external oblique fascia is carried out. The dissection is less extensive and bed rest and period of hospitalization is shortened in the patients so treated.

POSTOPERATIVE COURSE AND FOLLOW UP STUDY

The immediate postoperative course in groups I and II has been satisfactory. All patients wore a suspensory for 7 days. Little or no testicular edema has occurred and no thrombosis of the pampiniform plexus has been observed. The patients in group I are allowed up after several days and are back to duty in 10 days. The patients in group II remain in bed for 10 to 16 days depending on the size of the original lesion after which they are allowed up and participate in graduated



Fig. 14, left. Preoperative photograph¹ of patient with a left varicocele and a left indirect inguinal hernia reaching midway into scrotum.

Fig. 15 Postoperative photograph of same patient as in Figure 14. Note inguinal incision, absence of hernia and varicocele, and elevation of testicle.

exercises, and in 16 to 21 days they are discharged to the convalescent program. They are back to full duty in 3 to 6 weeks.

Follow up on 10 patients in group I indicates that ligation at the external ring is not entirely satisfactory as shown in Table II. For example hydrocele, testicular atrophy, nonrelief of pain, failure of suspension of testicle and persistence of varicocele, were seen one or more times. The shorter period of convalescence is an advantage mitigated by the poor postoperative results.

The best and most uniform results were observed in group II following the combined operation. Twenty two of these patients have been observed for a period of 3 months to 15 months. Pain has been relieved in all and no testicular complications have developed. The left testicles were well suspended at the level of or higher than the ones on the right side. The remaining 10 patients on whom the combined operation has been done within the last 3 months show no evidence of testicular disturbance whatsoever. It is logical that such would have occurred if the venous circulation had been rendered inadequate. Figure 14 shows a patient with a varicocele and hernia before operation and Figure 15 shows the same patient after operation. Note the inguinal incision, higher position of testicle, absence of hernia and disappearance of varicocele.

There is no comparison between the excellent postoperative condition of the patient following

the combined operation and the old operation through the scrotum. He is free of pain, has no testicular or scrotal swelling or induration and is cognizant of the well-being of the left testicle. He has had recurrence of neither varicocele nor hernia.

SUMMARY

- 1 The venous circulation of the testicle is composed of a primary or deep system (internal spermatic, originating in the pampiniform plexus: the ductus deferens and external spermatic veins) and a secondary or superficial system (superficial and inferior epigastric, superficial internal circumflex and the scrotal branches of superficial and deep external pudendal veins and the internal pudendal vein). The external spermatic and its cremasteric branches connect the two systems.

- 2 The varicocele is due to a distention of the pampiniform plexus by a static column of blood in the internal spermatic vein.

- 3 Ligation of the internal spermatic vein at the internal inguinal ring does not interfere with the collateral venous circulation between the two venous systems through the pampiniform plexus. It eliminates the static column of blood producing the varicocele. This approach also permits correction of the inguinal hernia if one is present, and permits suspension of the testicle.

- 4 The old type of varicolectomy through the scrotum for excision of the internal spermatic veins at their point of origin interferes with the collateral circulation between the primary and

¹Official Photograph, U. S. Army Air Forces.

secondary systems. This may explain the frequency of hydrocele following this operation.

5. Ligation of the internal spermatic veins at the external inguinal ring may also impair the collateral circulation but to a lesser extent. Were it not for this fact, this procedure would be advantageous when the varicocele is uncomplicated by a hernia, because of the shorter period of convalescence.

6. The association of inguinal hernia and varicocele in 14 to 25 per cent of patients referred for operation for hernia or varicocele or both has been observed clinically. At operation all of the 32 patients having the combined operation had a demonstrable hernial sac, an incidence of 100 per cent. The hernia may be the cause of pain in patients with varicocele and failure to correct it may be the reason for the persistence of discomfort in patients having had the old type of varicocelectomy.

7. The combined operation, as described, is the procedure of choice when a varicocele is associated with an inguinal hernia. It consists of ligation of the internal spermatic veins at the internal inguinal ring, ligation of the hernial sac, muscular

suspension of the testicle, and a modified type of herniorrhaphy. Testicular complications have not been observed following this operation.

8. The combined operation may be modified to meet a given situation, i.e. either ligating the internal spermatic vein at the internal inguinal ring *per se* in the absence of a hernia or ligating the vein and the hernial sac (if small) and closing in layers.

9. No recurrence of either the varicocele or of the inguinal hernia has been observed following the combined operation.

10. This study is based on a series of 145 cases of varicocele, 41 of which had ligation of the internal spermatic vein at the external ring, 32 had the combined operation, and 72 were not operated upon.

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PRIMARY MASCULINIZING TUMORS OF THE OVARY

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OF ALL the neoplastic growths which are to be found in the human body the most interesting are those that function much as any normal organ. This group of neoplasms may affect astoundingly the physiology of the body through the formation of hormones. Included among these tumors are the adenomas of the parathyroid and the islands of Langerhans, and the eosinophilic and the basophilic adenomas of the pituitary.

Several of the best examples of physiologically functioning neoplastic tissue are the feminizing and masculinizing tumors of the ovary. The most common one is the granulosa cell tumor which secretes estrone, resulting in precocious sexual development in young girls or a return of menstruation in women past the menopause.

There are two masculinizing tumors of the ovary—the arrhenoblastoma and the adrenal cell tumor of the ovary between which it is almost impossible to make a clinical distinction.

The arrhenoblastoma was named by Robert Meyer the term being derived from the Greek *arrhenos* meaning male.

After thorough study, Edgar Norris concluded that the term arrhenoblastoma should be used only when both the clinical and pathological observations justify its use—that is to say it is a clinicopathological condition. The term should be reserved for those cases in which there are definite evidences of defeminization and possibly masculinization associated with an ovarian tumor which microscopically can be so classified. Thus, one is unable to make the diagnosis on the microscopical appearance alone.

Study of the literature reveals this tumor to be quite uncommon. In 1938 Novak (18) reported that there were 45 cases of arrhenoblastoma and added 6 others. Norris, in a critical study excluding cases with no virilism, reduced the number to 29. We have been able to find 20 additional cases. Novak (20) in 1941 estimated that not over 60 acceptable cases had been reported.

The first case of arrhenoblastoma was reported in 1905 by Pick in Germany. This was a tumor containing a cellular arrangement very closely resembling the seminiferous tubules of the testis, and he, therefore, called it a testicular tubular adenoma. In 1915 Bell in England made two notable observations—the associated masculinizing changes

and also the presence of interstitial lipid containing elements upon which the degree of masculinization depended. Meyer in 1915 attempted to classify the pathological pictures of the tumor dividing them into 3 groups—the *adenoma testiculare* which is the same as in Pick's original case and is predominantly tubular—an *atypical group* which appears quite sarcomatous and produces striking masculinizing changes—and an *intermediate group* which is a mixture of typical and atypical tubules as well as solid portions and in which the clinical picture is intermediate between the first two. The first case of arrhenoblastoma in American literature was that reported by Taylor, Wolfemann, and Krock in 1933. However in 1921 Moots had reported a case of virilism under the title, Lateral Partial Glandular Hermaphroditism, and thus it is now believed was an arrhenoblastoma.

The terminology of the adrenal cell tumor of the ovary is very confusing in part due to the uncertainty of its origin. Cases are reported under a variety of names, among them hypernephroma, adrenal cell rest, and luteoma. Because of this confusion Rottino has suggested the term 'masculinovoblastoma'.

The term 'hypernephroma of the ovary' was introduced by Peham in Germany in 1899 and possibly we should give him the credit of reporting the first case, except that there was no typical masculinization. In 1908 Bovin reported the first typical case, but even this tumor was probably parovarian in origin.

The adrenal cell tumor of the ovary is quite rare. In 1938 Rottino summarized 7 cases and added 2 more. In 1944, Kepler and associates summarized the histories of 14 cases including one of their own. To these we must add the case reported in 1944 by Greene and Lapp as well as the 1 reported here making a total of 16. There are undoubtedly other cases reported under other diagnoses, as was Maxwell's case which is now classified as an adrenal cell tumor but was reported as an arrhenoblastoma.

SYMPTOMATOLOGY

The changes which usually take place in a person with a masculinizing tumor may be divided so that there will be first a loss of femininity and later possibly masculinization.



Fig.

Fig. 1. Masculinizing ovarian tumor removed from woman giving 6 year history of defeminization and masculinization.



Fig.

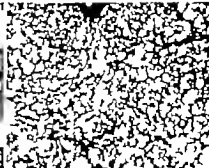


Fig. 3.

Fig. 3. Cross section of tumor.

Fig. 3. Photomicrograph of section of tumor showing typical adrenal cortical cells.

Defeminization. Usually there is first of all a persistent amenorrhea with sterility and then an atrophy of the breasts. The external genitalia are usually normal. There may be an abnormal change in the deposit of fat so that there is a loss of the rounded contour characteristic of the female. The heterosexual libido usually remains unchanged with the exception perhaps of late in the disease.

Masculinization. Hirsutism usually appears rather early and the beard may become quite heavy even requiring a daily shave. There is masculine distribution of the pubic hair and a recession of the hair line of the head. The skin becomes dark and rough and acne is quite common. There is a lengthening of the vocal cords resulting in a voice of lower register. An 'Adam's apple' may result from an overgrowth of the laryngeal cartilages. The clitoris is usually hypertrophied after several years.

If there is a typical picture of defeminization and then masculinization associated with a tumor of the ovary clinically the working diagnosis should be arrhenoblastoma because of a greater frequency though one must consider the adrenal cell tumor of the ovary and also bear in mind that in many cases one may find only an ovarian cyst with masculinization resulting from another cause.

It is practically impossible to differentiate the adrenal cell tumor from the arrhenoblastoma. However masculinization resulting from the arrhenoblastoma is essentially the same as that resulting from excess administration of testosterone. In fact, the changes are thought to be due to the production of testosterone or a similar hormone by the Leydig cells which constitute part of this tumor. On the other hand as Kepler has pointed out, when the changes result from adrenal

cortical hyperplasia or adrenal rest tumors of the ovary there are definite metabolic disturbances resulting in the so called Cushing syndrome. In these cases of masculinization one usually finds an associated hypertension, polycythemia, and diabetes. The hypertension may be due to overproduction of some compound similar to desoxycorticosterone the diabetes may be caused by the adrenal diabetogenic hormone there is no suggestive cause of the polycythemia. In differentiating these tumors Kanter stresses the importance of chemistry studies. If the masculinization results from an adrenal tumor there will be a decrease in the serum sodium and an increase in serum potassium, while the urinary sodium is increased to three times the normal and the potassium is decreased. Also if the virilism results from adrenal cells, the nitrogenous retention may be five or six times the normal. The sex hormone secreted by the adrenal cells produces sex characteristics of the opposite sex, so that a woman develops amenorrhea breast atrophy enlarged clitoris, and hirsutism while the male has breast hypertrophy testicular atrophy female distribution of adipose tissue, and loss of libido.

The masculinizing syndrome may be caused by several conditions and we must differentiate in particular those cases caused by ovarian tumors from the following. An adrenal cortical tumor may be demonstrated by the x ray after the perirenal injection of air. Cushing's disease or basophilic adenoma of the anterior pituitary gland is a polyglandular condition of pituitary origin with hyperplasia of the adrenal cortices and overactivity of the thyroid gland, there is amenorrhea loss of scalp hair hypertrichosis and often hypertension occasionally the clitoris hypertrophies an x-ray of the sella turcica would probably show evidence of the tumor.

Surgery is the treatment of choice for both types of tumor. The condition is usually unilateral and so the other ovary should be preserved, particularly in younger women. There have been many examples of pregnancy following the removal of these tumors. However it must be emphasized here that these tumors are malignant, or at least potentially so the growth being continuous and progressive with death resulting from malignant metastases. It is recommended that x ray be given if there are evidences of metastasis or recurrence radiation should be given in maximum dosages because less is stimulating.

After removal of the tumor there usually is a return of menstruation within a month. The breasts resume normal size in a comparatively short time. The disappearance of masculinization is much slower the hirsutism remaining for a very long time the hypertrophied clitoris may have to be amputated. If there is a recurrence there is again defeminization.

HISTOGENESIS

The origin of these tumors is still unknown but a number of theories have been postulated. Meyer and Novak believe that the arrhenoblastoma arises from embryonic remnants of the seminiferous tubules in the hilus of the ovary or as Bauer expresses it the arrhenoblastoma arises from vestigial male gonadogenic structures. McLester believes that the tumor is teratomatous in origin.

The most likely explanation of the origin of the adrenal cell tumor is that it arises from an adrenal cell rest in the ovary. However there are those who believe that it has a luteal cell origin.

PATHOLOGY

Arrhenoblastoma These tumors are unilateral and usually solid although some may be cystic. There may be degeneration. The size varies considerably some tumors attaining a diameter of 20 centimeters (6). The color is variable from a yellow to a reddish-blue. The one gross distinguishing feature is the presence of multicentric nodules. The microscopic picture varies considerably with the distribution of the epithelial cells (1) tubular (2) cylindrical, (3) diffuse or sarcomatoid. We must also recall the classification of Robert Meyer as presented earlier in this paper. There are pale staining interstitial cells, as reported by Bell, and the degree of masculinization is dependent upon the presence of such elements.

Microscopically the malignancy of these tumors is shown by the presence of multiple mitotic figures, variation in size and staining of cells, and large nucleoli. Regardless of the histological ap-

pearance clinically the tumor must be considered at least potentially malignant having a tendency to invade and to metastasize after years. While the growth is to be considered malignant and should be removed, other pelvic structures should not be disturbed at the time of operation.

Adrenal cell tumor of the ovary These tumors are also unilateral and vary considerably in size. Saphir and Parker reported one of microscopic size. The one reported in this paper measured 16 by 13 by 8 centimeters. All are solid. A characteristic gross feature is the golden yellow color. These tumors are usually encapsulated by thinned out ovarian cortex.

Microscopically the cellular picture is almost identical with that noted in the ordinary hypernephroma large granular polyhedral cells lie in a mosaic arrangement mainly around numerous, fine capillary vessels. There is very scant fibrous tissue. The sharply demarcated cell walls are quite striking never being found in the granulosa cell tumor or in a corpus luteum. These large polyhedral cells contain as a rule, lipid material glycogen has been found in several of these tumors.

All cases thus far reported have been benign except Smith's (25) case which was atypical in certain respects this patient died after 4 years. Kepler and Dockerty's tumor is histologically malignant. The case to be reported here is both pathologically and clinically malignant.

CASE REPORT

The patient was a 36 year old woman admitted to the hospital April 30, 1942, complaining of an abdominal tumor which was first noticed after dieting and losing 40 pounds of weight during the previous year. On questioning, she revealed that she had not menstruated since the birth of her second child 16 years before. Shortly after the birth of her child hirsutism began to develop, the face and neck became flushed and somewhat bluish, and the voice deepened. The patient was hiccupping occasionally at the time of admission.

Examination Blood pressure was 124/78. There was a bluish-red flush of the face, neck, and chest. There was a heavy beard that required daily shaving and a heavy growth of hair elsewhere, with a masculine distribution, the hair of the head was thin, and there was a recession of the hair line. The thyroid gland was not enlarged. There was a small "buffalo hump" in the cervicothoracic region. The abdomen was filled with what was apparently a multinodular tumor probably arising in the pelvis. On pelvic examination a small uterine tumor was found, apparently separate from the large abdominal tumor. The clitoris was not enlarged.

The red cell count was 4,500,000 the hemoglobin was 84 per cent, and the white cell count, 7,500. The urinalysis was essentially negative.

The clinical diagnoses were fibromyoma of the uterus and a multiple ovarian tumor probably arrhenoblastoma. Operation was performed under spinal anesthesia. The abdomen was opened, and a small amount of free fluid was

noted. The tumor in the lower abdomen was found to arise from the left ovary and to extend into the broad ligament. It was removed. The uterus, approximately four times the normal size, was not disturbed. The right tube and ovary were negative. The tumor mass felt in the upper abdomen consisted of a huge liver containing many nodules, some quite large. The spleen was approximately five to six times normal size. There was no other evidence of metastases.

After operation the axillary temperature was 102.8 degrees on the 3rd day but was normal the following day and continued so. The patient was troubled considerably with hiccupping during the entire postoperative course. The pulse was very rapid. On the 7th day she was quite bit weaker; the eyes and skin were observed to be jaundiced, and this was more pronounced the following day when she was somewhat moribund. On May 9, 9 days after operation, and the first time in about 6 years, there was vaginal bleeding. The following day she, as comatose, and death came the following night, 10 days after the operation. Unfortunately no autopsy permission could be obtained.

Pathology. The pathological studies were by Dr. Harry M. Weston. The specimen is an ovarian tumor measuring 6 by 3 by 8 centimeters having somewhat nodular surface. On sectioning, it shows numerous rounded to irregular areas presenting variety of colors, some being reddish-gray others yellow resembling corpus luteum, and others having hemorrhagic appearance. There is considerable grayish stroma. The fallopian tube, which is stretched over the tumor is essentially negative.

Microrhynchus examination. The tumor is moderately vascular. The outer capsule is covered by thin, fibrous capsule. Two types of cells seem to predominate. The cells of one variety are rounded to hexagonal and seem to be dispersed irregularly through light stroma with no definite arrangement. The nuclei are small and lie either in the center or to one margin of the cells. The cytoplasm is quite clear and slightly granular. The cells of the second variety lie somewhat in cords. The nuclei are rounded to oval and are somewhat in size. The cytoplasm is moderately dense and presents granular to fatty appearance.

Pathological diagnosis. Masculinizing ovarian tumor of adrenal cortical origin.

Sections of the tumor were examined by Dr. Emil Novak () who considers it malignant adrenal cell tumor originating in the ovary.

SUMMARY

Two masculinizing tumors of the ovary the arrhenoblastoma and the adrenal cell tumor of the ovary are discussed. Each is found to be quite uncommon and to produce a similar clinical alteration of physical appearance and sexual function, there first being a defeminization and later masculinization.

Surgery is the treatment of choice for these tumors, and if there be a recurrence, each tumor being at least potentially malignant, there is again defeminization.

A case is reported of a masculinizing ovarian tumor removed from a patient giving a clinical history of 16 years duration. At operation numerous metastases were found in the liver and subsequent coma suggested cerebral involvement. Nine days after removal of the tumor menses began for the first time in 16 years. The patient died on the 11th postoperative day. Autopsy permission was refused. Histologically the tumor was of adrenal cortical cell origin, primary in the ovary.

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SACROCOCCYGEAL SINUS (PILONIDAL SINUS) IN DIRECT CONTINUITY WITH THE CENTRAL CANAL OF THE SPINAL CORD

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THE embryologic origin of sacrococcygeal sinuses has been in dispute since the very time of the description of the entity itself. This has, in general, been resolved to two opposing theories: (1) that they result from persistence of coccygeal vestiges of the neural canal and (2) that they are the result of invagination of the surface epithelium. The former theory appears to be the most widely held and best supported (6, 7, 10, 12) but the latter has its firm adherents (2, 4, 5, 15).

In support of the first theory, evidence is presented from the study of embryos that the caudal end of the neural canal is early pinched off and an epithelial sac communicating with the skin in the sacrococcygeal area is produced. Just proximal to this the neural canal seals off and forms the filum terminale. Generally the caudal epithelial sac atrophies and disappears about the 5th intra-uterine month. It is the persistence of this sac that forms sacrococcygeal cysts and sinuses according to the first theory. In confirmation of this supposition are several case reports which describe sacrococcygeal sinuses as being in connection with the dura or even running subdurally as dermoid cysts (1, 9, 14, 16). In a few patients it has been inferred that sacrococcygeal sinuses communicate with the subarachnoid space because of the presence of a thin, watery discharge from the sinus, regarded as cerebrospinal fluid, or because of the development of meningitis in these cases (11, 13). In none of these latter cases was an autopsy performed and the exact relationship of the sinus to the central nervous system could not, therefore, be demonstrated. For commenting on such cases, expressed the opinion that a few drops of clear fluid discharged from the sinus could not be accepted unquestionably as being cerebrospinal fluid and that the occurrence of a meningitis associated with a dermal sinus might result merely from a lack of bony protection or

from extension by way of the lymphatics or blood stream.

In the case to be reported here, with complete autopsy studies, the relationship of a sacrococcygeal dermal sinus to the central nervous system is demonstrated. We believe, therefore, that the embryological origin of sacrococcygeal sinuses, or pilonidal sinuses, is in relation to persistent sacrococcygeal remnants of the neural canal rather than primarily due to a faulty development of the surface epithelium.

REPORT OF A CASE

A K. male child 22 months of age was admitted to the Hospital of the University of Pennsylvania with acute urinary retention of 30 hours duration. There had been no antecedent infection nor were there accompanying symptoms other than progressive irritability incident to the distention. Family and birth histories were of no significance and the child had developed normally, both mentally and physically. At birth, a small cyst had been noticed at the base of the spine. X-ray pictures were taken and the mother was informed that the lesion was of no importance. It had been decided that surgical excision was not necessary.

Physical examination revealed a well-nourished child in acute distress. The rectal temperature was 101.3 degrees F. The lower abdomen was exceedingly tender and the bladder was palpable at the umbilicus. The neurologic examination was negative. Over the sacrum, in the midline, was a soft, pink, round mass, about 2 centimeters in diameter at the inferior margin of which was a minute sinus opening. The mass was not inflamed or tender.

Catheterization yielded 350 cubic centimeters of clear urine. The patient was immediately relieved and began taking fluids well. A retention catheter was left in place. For the next 3 days he ran a steady fever of 101.1-101.3 degrees, which was assumed to be the result of urinary tract infection. He was given sulfamerazine in dosage sufficient to maintain a blood level of 15.0 milligrams per cent. However, he became slowly but steadily worse. He was less active and no longer walked about the crib. On his fourth hospital day, there was a quiet, male nuchal rigidity and a slightly positive Kernig sign. These symptoms became very pronounced during the next 24 hours. A lumbar puncture was performed. A small amount of thick, yellowish-brown, foul smelling fluid was obtained. The fluid was loaded with polymorphonuclear leucocytes. There was too slow to obtain a pressure reading and the amount obtained was insufficient to make possible a protein determination. Culture revealed numerous organisms, most of the streptococci diptheroid, and gram-negative aerobic non-spore-forming bacilli of the bacteroid group. On 11/15/52

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day examination revealed complete paraplegia and anesthesia of both lower extremities and of the perineal region. Lumbar puncture again revealed thick foul-smelling purulent material. Cisternal puncture yielded a cloudy but thin fluid, the culture of which revealed organisms identical with those obtained on lumbar puncture.

The opinion at this time was that the child was suffering from meningitis and the difference in consistency of the lumbar and cisternal fluids indicated the presence of at least a partially localized abscess in the lumbosacral portion of the intravertebral canal. The rapidly developing transverse myelitis substantiated this. The mixed type of infection, and particularly the presence of an anaerobic organism, pointed to an extrinsic source of contamination. The sinus leading from the sacral dimple seemed the most likely avenue for the entrance of the infection. The only other positive finding was polymorphonuclear leucocytes ranging from 7,000 to 6,500. Within few hours after the development of the transverse myelitis, laminectomy was performed.

Operation. The first to the fourth lumbar laminae were removed. The posterior epidural space was clear and, therefore, the dura was opened and cloudy, obviously infected, spinal fluid flowed into the wound. This, however, did not resemble the thick, purulent fluid previously obtained on lumbar puncture. The exposure was such that the lower end of the cord, the conus and the beginning of the cauda equina could be seen. The dorsal surface of the cord as exposed in three or four spots. These small areas were about 2 to 3 millimeters in diameter and appeared to be brown. On retraction of the cord laterally, toward the right, a pocket was found, anterior to the cord, containing free pus and many bits of cheesy and necrotic material. A rubber tissue drain was placed in this pocket and let out through the lower end of the incision. The dura was left wide open, the meninges were brought together with wire, and the subcutaneous tissue and skin were closed with silk suture.

The child failed to rally following operation, continuing with high fever (40-42°). He was restless and vomiting and finally passed into coma, dying 50 hours after operation.

Autopsy report. The thoracic and abdominal viscera were grossly and macroscopically normal, save for the lungs and the urinary bladder. The former showed passive congestion and the latter cystitis. Beneath the wound, over the lumbar vertebrae, there was an area of purulent reaction in the subcutaneous tissue and, beneath this, a purulent cavity where the lumbar spines and laminae had been resected. The dura in this area was partially open and the rubber drain curled in the subarachnoid space, around the cord as its anterior surface. The cord was completely surrounded by sticky greenish bits of exudate which appeared to be too thick to drain. This exudate was adherent to the cord and to the arachnoid as high as the dissection was carried, which was about the seventh cervical vertebra. The extradural space was entirely free of pus. The lower end of the sacrum had 6 millimeter blattas and the skin dimple over the sacrum was connected by a lead-like band, through this blattas, with the lower portion of the spinal dura. Tension on the skin moved the dura downward. Injection showed the extradural portion of this tract to be patent, and radiopaque oil was injected through the skin dimple and demonstrated to be like the spinal canal (Fig. 1). Dissection revealed the conus medullaris to be in direct continuity with large cystic dilation of the filum terminale which was filled with pus and measured approximately 4 centimeters in length and centimeters in diameter. The long roots of the cauda equina surrounded this pus-containing sac and were themselves heavily cov-

ered with thick, purulent exudate. The dilated, pus-filled filum terminale could be demonstrated to be in direct continuity with the sinus opening into the sacral dimple below and with the central canal of the spinal cord above (Fig. 1). This sac was, however, partially divided into two compartments, the more caudal compartment containing thicker fibrin, in clumps. The spinal cord, on multiple transverse section, was seen to be swollen and the seat of numerous, fresh, small hemorrhages, as high as the ninth thoracic segment. The gross architecture of the lumbar portion of the cord was entirely distorted. The brain, which weighed 850 grams, revealed flattening of the cerebral convolutions and the meninges. In the depths of the sulci, contained slight amount of milky exudate. The basilar surface of the brain was covered with thick, greenish-white, purulent exudate extending from the medulla rostrally over the inferior surface of the cerebellum, pons and mid-brain and filling the interpeduncular space. The ventricular system showed moderate, symmetrical dilatation, but there was no gross evidence of an ependymitis. The cerebral hemispheres were considerably swollen and there were many petechial hemorrhages, particularly in the central white matter in relation to the lateral ventricles, in the pons, and in the white matter of the cerebellum.

Microscopic examination. The contents of the intra-vertebral canal from the ninth thoracic vertebra to the sacrum, including the dorsal sinuses, were sectioned transversely into centimeter blocks, from each of which representative sections were cut and stained. Several of the blocks were cut serially. The dorsal sinuses were lined with stratified squamous epithelium and contained small amount of epithelial debris. The subjacent tissues were heavily scarred. The sinus opened directly into the widely dilated sac-like cavity surrounded by the roots of the cauda equina. The cranial portion of this cavity was also lined by stratified squamous epithelium and in its wall were well formed hair follicles and sweat glands (Fig. 2). Its walls also contained many inflammatory cells and engorged small blood vessels. The epithelial lining was destroyed in many places and the lumen contained thick, purulent exudate in which much debris of epithelial origin could be distinguished. The rostral portion of the cavity was lined by a single layer of low columnar cells (Fig. 4) and could be demonstrated to be continuous with the central canal of the lumbosacral cord. The exudate in the central canal and the rostral portion of the sac communicating with the dorsal sinuses was purulent but did not contain the epithelial debris present in the lower portion of the tract. The block containing the communication of the two differently lined portions of the dilated and cystic filum terminale was sectioned serially and revealed that these two portions overlapped each other and made side to side junction (Fig. 3). Extraordinarily there was no break in the structure to indicate the site of this division. Figure 6 shows the microscopic appearance of the junction of the two different types of lining of the cavity.

The spinal cord, as high as the ninth thoracic segment, was the site of centrally located, partially encapsulated abscess (Fig. 7). The abscess was about the central canal and had destroyed most of the gray matter. About the periphery of the abscess was moderately heavy glial proliferation which had formed only partial capsule. No connective tissues had been laid down in the abscess wall. The remaining portions of the cord were edematous, infiltrated with mononuclear cells, and contained proliferated, hypertrophied glial elements. Where the anterior horns were not completely destroyed, the ganglion cells were in all the various stages of necrosis and many had already disappeared.



Fig 1. Roentgenogram of specimen demonstrating continuity of sacrococcygeal sinus with intervertebral canal. Radiopaque oil has been injected through sinus in skin dimple.

The subdural and subarachnoid spaces can be considered as a whole since the arachnoid could not be identified. These spaces were filled with thick, purulent exudate. This exudate, in the lumbosacral region, was composed chiefly of lymphocytes and plasma cells in a network of heavy collagen and precollagenous tissue and newly formed blood vessels. The nerve roots were deeply encased in this organized inflammatory tissue. Immediately beneath the dura, the exudate appeared to be more recent, being composed chiefly of polymorphonuclear leucocytes, with little or no evidence of organization. The dura was intact for the most part but was infiltrated with inflammatory cells. At the operative site, the dura was much thinned and more heavily infected, with an acute, purulent exudate covering its outer as well as its inner surface.

The thoracic meninges were also filled with a thick exudate, but this was composed almost entirely of polymorphonuclear cells with little connective tissue proliferation. The meninges at the base of the brain were filled with a purulent exudate consisting of many polymorphonuclear cells, fewer mononuclear cells, and necrotic debris. An inner layer of this meningial exudate at the base of the brain appeared to be of longer standing. This consisted chiefly of lymphocytes, plasma cells, and fibroblasts, in a network of fibrin and young connective tissue. The ganglion cells of the brain stem showed both mild and severe toxic changes. The meninges over the convexity of the brain revealed a patchy infiltration of inflammatory cells, most marked in the sulci. This infiltration consisted chiefly of round cells with occasional clumps of polymorphonuclear cells and some necrotic debris in the depth of the sulci. The meninges over the hippocampal gyrus revealed a more acute, necrotizing suppurative inflammation than was seen over the dorsolateral aspect of the brain. The cortex everywhere appeared edematous and the cells showed toxic changes.

In summary the anatomic findings in this case demonstrate a dermal sinus, presenting in a sacrococcygeal dimple to be in direct continuity with a patent and dilated filum terminale which, in

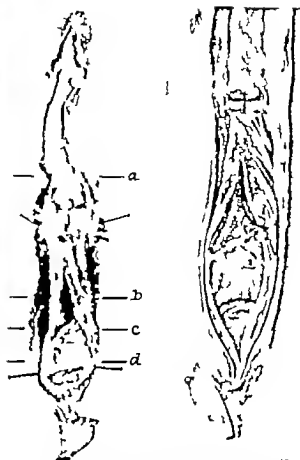


Fig 2. a, left, Photograph of autopsy specimen. b, c and d are the levels from which photomicrographs (Figures 3, 4, 6, 7) are taken. b Artist's conception of a, showing in detail the relation of the skin dimple and dermal tract to dilated filum terminale. A probe can be seen passing from rostral portion of filum terminale up through the central canal of the spinal cord.

turn, is in continuity with the central canal of the spinal cord. This is therefore a concrete example of the relationship of sacrococcygeal dermal sinuses with abnormalities in development of the neural canal. It is the failure of obliteration of the coccygeal medullary vestiges, as described by Herrmann and Tournoux and emphasized by Gage, that may give rise to these congenital developmental lesions. This case indeed proves the hypothesis which Gage drew from his embryologic studies, viz. that a sacrococcygeal sinus could be in continuity with a persistently patent filum terminale and even the spinal cord.

Walker and Bucy thought that cases of dermal sinuses communicating with the contents of the intravertebral canal at higher levels than the sacrococcygeal region were evidence against the theory of a persistent neural canal as the origin of the histologically similar sacrococcygeal dermal sinuses, in so far as it failed to explain the former situation. Nevertheless, they offer as an ex



Fig. 3.



Fig. 4.

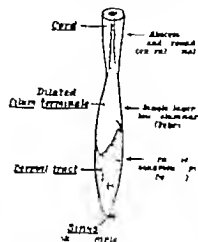


Fig. 5.



Fig. 6.

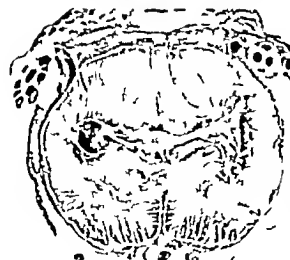


Fig. 7.

Fig. 3. Stratified squamous epithelium lining and dilatation of the dermal sinus. A hair follicle is present in the upper left corner. Section is from level, d. (hematoxylin and eosin, $\times 70$).

Fig. 4. Columna epithelium lining rostral portion of cavity. Ectoderm is present in the lumen. Section as indicated a, b, in Figure 2. (hematoxylin and eosin, $\times 40$).

Fig. 5. Diagram of lateral view of specimen illustrating the mode of communication of the dilated filum terminale with the dermal tract.

Fig. 6. Junction of the differently lined portions of the dilated filum terminale. Section is through level i in Figure 2. (hematoxylin and eosin, $\times 4$). The insert in lower left corner shows the columna epithelial lining of left portion of cavity (hematoxylin and eosin, $\times 40$). The epithelial lining of the right portion of the cavity, which is in continuity with the differently lined tract, has been destroyed at this level.

Fig. 7. Abscess about central canal of lumbar cord. Level at, a, as indicated in Figure 2. (hematoxylin and eosin, $\times 6$).

planation for these cases of higher segment dermal sinuses, the theory of imperfect cleavage of cutaneous epithelial ectoderm in the first intrauterine month. Thus, the neural tube carried down with it a narrow invagination of skin. Thus, they felt supported the hypothesis of cutaneous ectodermal invagination as the origin of sacrococcygeal dermal sinuses. This is rather confusing until it is realized that the proponents of this latter theory think of the abnormality in development which leads to pilonidal sinus formation as lying entirely within the cutaneous ectoderm. Therefore Walker and Bucy's cases, and even their own hypothesis of origin, support the concept that the abnormality is principally a faulty development of the neural canal. Kooistra in presenting a case of pilonidal sinus occurring at the level of the third thoracic spine and communicating with the spinal cord, also stated a belief that faulty development of the neural canal is the basis of these congenital lesions. However failure to demonstrate a connection with the central canal in any reported case is offered as an objection. The case described in this paper meets even this objection.

The meningeal and intramedullary infection producing the clinical picture which brought the patient to our attention traversed the patent pathway from the sacrococcygeal sinus. Spinal cord abscess is rare usually occurring as a metastatic lesion in general sepsis. This fact plus the rarity of the malformation present in this case makes it understandable that the diagnosis was not made earlier in the course of this patient's hospital stay. It was the opinion of the urologist who performed the catheterization upon this patient that a congenital urethral band or stricture was the cause of the urinary retention. The pediatricians, who saw the child during the first few days suggested that the retention might be the first clinical effects of a spina bifida occulta. Spinal cord or meningeal infection was not considered until the appearance of the nuchal rigidity and the possibility of a localized abscess in the lumbar region was not taken into consideration until after the development of the paraplegia.

However in view of the location of the abscess, it seems unlikely that surgical intervention at any stage of the process could have been entirely successful. Had the sacrococcygeal sinus been removed earlier in the life of this child, it is possible that such a bizarre and tragic termination might have been prevented. This case serves, therefore, to emphasize the recommendation of others (3) namely that a persistent congenital sinus in the midline of the back should be excised.

SUMMARY AND CONCLUSIONS

1. A case is presented in which a congenital sacrococcygeal dermal sinus was in direct continuity with an abnormally patent and dilated filum terminale and the latter in turn with the central canal of the spinal cord.

2. This is offered as evidence that sacrococcygeal sinuses (pilonidal sinuses) originate as a malformation in the development of the neural canal.

3. The development of an intramedullary spinal cord abscess and a purulent meningitis by contamination through the dermal sinus in this case indicates the importance of early excision of such congenital lesions.

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THE PATHOLOGY OF EXPERIMENTAL CLOSTRIDIAL INFECTIONS IN DOGS

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In 1900 Welch published his observations on the morbid conditions caused by gas gangrene organisms. He pointed out that the liver was the seat of early and abundant development of gas. Rabbits killed a few minutes following the intravenous injection of the gas bacilli and kept in a warm place for 6 to 8 hours were found to have a large amount of gas in the blood organs, and other tissues. This accumulation of gas was thought to be the result of air embolism. Gas was also seen in the lymphatics, mesentery omentum and peritoneal cavity. Welch demonstrated that the gas bacillus may multiply in the body without gas formation and called attention to the fact that the bacilli may be seen in clumps in the spleen and kidney surrounded by necrosis but without gas. He also reported 1 case of meningitis and 1 case of gas gangrene of the brain with cavity formation. Most of the cases which he observed represented gas bacillus growth in the body after death.

Kaufman described a fatal case of gas gangrene in which the heart spleen liver and kidney were swollen soft pale spongy and honeycombed with innumerable tiny cavities. The myocardium had gas filled spaces. He concluded that the muscles are usually soft vacuolar and waxy with laminated destruction. The muscles showed edema associated with hemolysis, innumerable bacilli, fibrin and leucocytes. The gases encountered were thought to result from the bacterial action on muscle glycogen. He attributed death to toxemia.

Callender and associates state that gas gangrene is essentially a disease of the muscles. They believe this predilection is principally because of the high glycogen and glutathione content. The disease is manifest within 6 to 48 hours following infection. The muscles swell in the sheaths and the infection travels upward rarely laterally. There is an absence of inflammatory reaction. The path of the infection (Eliason and associates) follows the muscle bundles. Complete muscle de-

generation results from the interruption of the blood supply which is brought about by the excessive swelling.

The gas gangrene bacilli are incapable (Ireland and Coupal) of producing the disease by their presence alone. Failure of circulation damaged tissue, and a progressive increase of these factors are necessary in order to produce the true clinical picture of the disease. Ireland and Coupal believed that death intervened by respiratory failure rather than by cardiac paralysis.

Pasternack and Bengtson studied the changes produced by the toxin of *Clostridium septicum* in rabbits, mice guinea pigs, and pigeons. They concluded that hyaline degeneration was the essential and most important lesion of the heart, and that this was the probable cause of death in gas gangrene. If the animal survived over 4 days, fibroblastic scars of the myocardium were seen. The cardiac ganglia showed no changes. The liver revealed lesions in a small percentage of animals. It was often engorged by red blood cells. They found a nephrotoxic property of the toxin.

Sewell reported a case in which there was gas gangrene of the trunk with recovery and residual cardiac damage.

The route by which the toxin is given is important and has a bearing on the type of damage. Mice and rabbits die by receiving intravenous toxin of *Clostridium septicum*. When the toxin is given subcutaneously in guinea pigs, it fails to produce death, even when large doses are given. Severe local necrosis may result and the animal usually recovers. This is true when the toxin is given intramuscularly (Bengtson and Robertson).

Clostridium welchii also produces hemolysis for red blood cells of most animals including chickens (Ireland and Coupal).

W. Straub and Lautenschlager working with "gasoedema" toxin stated that it "had an action like that of digitalis on the isolated frog's heart and that this action was blocked by antitoxin."

In our experimental work on gas gangrene in dogs, we have seen that the diseased muscles have returned to an approximately normal state in dogs which have recovered following treatment. The literature records repeated observations of skele-

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Fig. 1. Heart muscle, $\times 567$ showing relatively severe changes. Dog No. A 126 (18577). This dog was a control which had been inoculated with a mixed culture (No. 3) of gas gangrene organisms. The animal succumbed within 13 hours after it had been inoculated. Examination of the heart muscle revealed the presence of swelling, hyalinization, and fragmentation. Pallor of the nuclei is also seen.

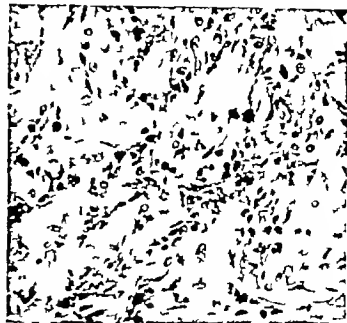


Fig. 2. Heart muscle, $\times 567$, showing organizing necrosis. Dog No. A 135 (Y8710). This dog was inoculated with a mixed culture (No. 3) of gas gangrene organisms. Therapy consisted of sodium sulfadiazine and antitoxin. Dog died 10 days after inoculation. Gastrointestinal tract was filled with bloody fluid and numerous ascariids. Section shows some of muscle fibers swollen with loss of striations and nuclei. Mononuclear cells and fibroblasts present.

tal muscle regeneration in cases of typhoid pneumonia injuries, wounds infections, and invasions by tumors, et cetera. Forbus gives a careful review of the subject of skeletal muscle regeneration. Volkmann believes that undisturbed sarcolemma is an essential requisite for the proper development of the regeneration of the muscle fibers. Experimental regeneration was produced as early as 1892 by Kirby. Olafson has produced experimental regeneration in the skeletal muscle in lamb. In reviewing our microsections he found that the regeneration as seen in his animals compares with that seen in skeletal muscle which has recovered from gas gangrene. Forbus presents evidence that regeneration of experimentally destroyed muscle is apparently total without scar formation.

Experimental. A large number of dogs were used in the study of the therapeutics of gas gangrene. The pathological material was studied in 96 of these dogs. Twenty six were untreated controls. Forty three received one or more therapeutic agents.

Healthy adult dogs were inoculated with a mixed clostridial infection. Untreated control dogs were inoculated either with the mixed infection or with the individual clostridial strains. The organisms used were *Clostridium welchii*, *Clostrid-*

ium septicum, *Clostridium novyi*, *Clostridium sordellii*, or a mixture of these four organisms plus *Staphylococcus aureus* (mixture No. 2). The inoculum, carefully prepared under rigid conditions and standardized as uniformly as possible, was grown in a Douglas heart infusion broth containing chopped beef heart. The method of inoculation was the same as previously described by Dowdy and Sewell.

The definitive agents for therapeutics were sodium sulfadiazine, penicillin, polyvalent gas gangrene antitoxin,¹ or combinations of these agents, administered intravenously. The dosage is indicated for each group studied (see Tables). Sodium sulfadiazine was administered so as to maintain as closely as possible, a continuous blood level of 15 to 20 milligrams per cent for the periods noted in the charts. The drug content of the blood was checked at frequent intervals. The therapeutic results of the various methods of treatment will be presented in a subsequent paper.

Autopsies were performed on representative animals selected from each experimental group as soon after death as possible. Most of the recovered dogs were killed by intravenous nembutal and chloroform. All of the organs except the brain and spinal cord were examined routinely. The

¹Underle's penitoxin.

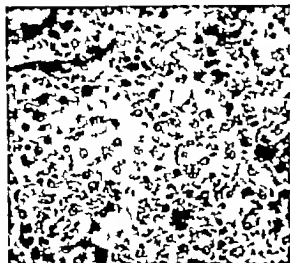


Fig. 3. Liver $\times 367$ showing focal injury of the liver cells. Dog No. A-66 (18547). This control dog, as inoculated the mixed culture (No.) of gas gangrene organisms. Death occurred 4 hours after inoculation. This microscopic section reveals marked engorgement of the sinusoids with red blood corpuscles. There is also revealed injury to the cells in the central portions of the lobules.

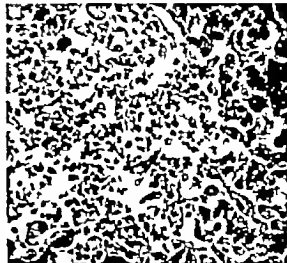


Fig. 4. Liver $\times 367$ showing an organizing focus of necrosis. Dog No. P-35 (18653). This dog, as inoculated the mixed culture (No.) of gas gangrene organisms and as treated with sodium sulfadiazine and penicillin. Recovery was satisfactory. The animal, as sacrificed days after inoculation. Note the necrosis of liver cells, the acute and chronic inflammatory cells, and the fibroblasts. Interstitial edema is seen in other portions of the liver.

brain and spinal cord were studied with negative results in 4 dogs dying of the infection. The spinal fluid was clear. We did not feel that nerve tissue changes were sufficient in these animals to warrant special staining techniques which are necessary to bring out detailed changes. Nerve bundles studied by ordinary hematoxylin and eosin stains showed no obvious changes even though some were seen in the midst of the area of severe muscle necrosis at the site of inoculation.

The tissues and organs of the body most involved were the inoculated muscles with their surrounding structures, and the heart and the liver. These will be discussed under the heading of each special group. The other organs revealed no significant changes. The kidneys remained remarkably free of any significant pathological changes in both the treated and untreated animals.

The pleural, pericardial, and peritoneal cavities contained the normal small amounts of clear fluid and their surfaces were smooth and glistening. The only exceptions were the pleural cavities in those dogs having an associated secondary bronchopneumonia of streptococcal or staphylococcal origin. In practically all instances the lungs remained pink and air-containing. The spleen was rarely enlarged or involved. The gastrointestinal tract was normal. The pancreas remained intact

and revealed no gross or microscopic lesions. The adrenals were of the usual size, cream-colored firm and free from lesions. The male genitalia were not involved. The testicles were free of involvement though frequently noted in close proximity to severe edema and necrosis which had spread from the initial site of inoculation. Two of the females had severe endometritis, apparently unrelated to the clostridial infection.

No thrombi were seen in the vascular system and the endothelium remained smooth and glistening.

The thyroid gland remained small in all dogs. It was firm and non-inflamed. The lymph nodes were not enlarged. (One dog had a coincidental generalized lymphosarcoma.) The bone marrow appeared normal in the gross. Only 2 dogs seemed to be anemic; however no blood studies were carried out.

In the following discussion, it will be assumed that the organs not mentioned were found to be normal or had insignificant changes. Only the inoculated site, the heart, liver and kidneys will be considered in the tables.

The inoculated site (right posterior thigh muscles) and the areas in close proximity were usually greatly swollen by pockets of gas or severe edema. In some dogs the gas was noted in the form of tiny bubbles throughout the tissues producing the

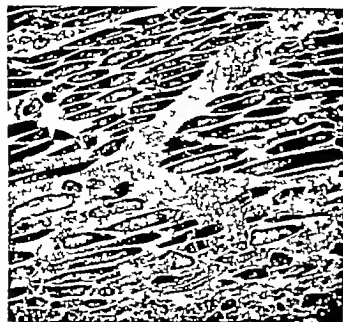


Fig. 5. Skeletal muscle, $\times 68$, at the site of inoculation with a mixed culture (No. 3) of gas gangrene organisms Dog No. A 103 (18543). This control dog died 37 hours after it had received the inoculation. There are numerous erythrocytes and much fibrin. Examination reveals that the muscle fibers are atrophic and hyalinized. Their nuclei are lost. Edema, inflammatory cells, and pockets of gas are seen.



Fig. 6. Skeletal muscle $\times 267$ at the site of inoculation with a mixed culture (No. 3) of gas gangrene organisms, showing repair Dog No. AP 13 (18674). Therapy used sodium sulfadiazine, penicillin, and antitoxin. Recovery satisfactory and dog sacrificed 13 days after inoculation. Numerous acute and chronic inflammatory cells and fibroblasts present. Large oval muscle cells are growing and developing new nuclei and show muscle striations.

appearance of a fine sponge. The edema of the muscles consisted of a diffuse dark red serous guineous fluid. The muscles were mottled and necrotic. Often large pockets containing a dirty gray pus mixed with pieces of necrotic tissue were found. In some of the control animals surviving longer than 36 to 48 hours the muscles were entirely destroyed leaving intact the skin, blood vessels, nerves, and strands of dense connective tissue. The necrotic process stopped at the attachment of the thigh muscles to the pelvis. In a few animals the abdominal muscles were edematous and mottled with red.

Microscopically the diseased muscle appeared as a diffuse mass of fibrin and degenerated red blood corpuscles. Only remnants of muscle fibers remained surrounded by connective tissue and an extensive interstitial edema. Many of the

muscle fibers showed a loss of nuclei. Bacilli were often present and small pockets of gas were seen.

The heart was found to be dilated in most of the animals examined post mortem. The walls were moderately thin and the parietal pericardium and endothelial linings were smooth and glistening. The papillary muscles and cords and the valves were not remarkable. Some heart muscle changes were present in practically every instance. These changes were scattered throughout various parts of the heart muscle and since the entire heart was not studied under the microscope we must assume that lesions were often missed. The pathological changes consisted of areas of moderate to severe fragmentation of the muscle fibers with swelling, loss of striations, pallor, fine and coarse granular degeneration. Many of the fibers contained round clear vacuoles. The nuclei showed little change except in rare areas of frank necrosis. Frequently there were seen scattered areas of Zenker's 'waxy' degeneration of the muscle fibers. This consisted of hyalinized areas of muscle which took either an eosinophilic stain or a blue stain. Marked vascular engorgement with red blood corpuscles was common. Some tiny areas of early necrosis and severe edema were found. In dogs which had received therapy these necrotic areas were seen as small foci of chronic inflammatory cells and fibro-

THE PATHOLOGICAL CHANGES IN UNTREATED CONTROLS—SEE TABLE I

Infection agent	Number of dogs
<i>Clostridium welchii</i> (<i>Clostridium perfringens</i>)	5
<i>Clostridium septicum</i>	3
<i>Clostridium novyi</i>	3
<i>Clostridium sordellii</i> (<i>Clostridium bifermentans</i>)	6
Mixed infection #3	0
Total	16

Clostridium welchii, *Clostridium septicum*, *Clostridium novyi*, *Clostridium sordellii*, plus *Staphylococcus aureus*.

TABLE I.—UNTREATED DOGS INOCULATED WITH CLOSTRIDIA

Dog No	Age in years	Time of death in hours post-inoculation	General condition	Pathological changes ¹⁰				Miscellaneous
				Heart	Leg	Liver	Kidney	
Mixed Culture X								
A 101		14	Fair					Bulging vessels on abdomen
A 87		27	Fair/Best					
A 18			Poor					
A 184		26	Poor					Congestion of lung vessels
A 109			Fair/Best					
A 146		28	Fair/Best					
A			Fair/Best					Brachycephalus
A 14			Fair/Best					
SpC		40	Fair/Best					Brain stem normal
Clostridium septicum								
A 27		43	Fair/Best					Brachycephalus
A		34	Fair/Best					Brachycephalus
A 29		5	Poor					
Clostridium novyi								
A 46	18	50	Fair/Best					Brain stem normal
A 14		46	Fair/Best					
A-143		29	Fair/Best					
Clostridium ordalii								
P 20	10		Good					
P 14			Good					
P		46	Good					Brain stem normal
AP		27	Fair					
AP		26	Fair					
AP 43		46	Good					
Clostridium welchii								
AP		14	Good					
AP		27	Good					Brachycephalus, brain stem normal
AP 6			Fair					
P			Fair/Best					
P-1		6	Good					

¹0, No changes; 1, slight change; 2, moderate change; 3, severe change.

blasts with early organization. Cardiac nerve bundles were often seen and were found to show no significant changes.

The liver in all instances was markedly engorged with red blood corpuscles. The sinusoids were greatly distended and the central portions of the lobules were often so distended with red blood corpuscles that the liver cells were flattened and destroyed. Small areas of focal necrosis were frequent. In some instances the liver revealed severe

generalized damage as evidenced by marked interstitial edema and large areas of early necrosis. The cells were swollen and their nuclei pale.

Some of the liver cells contained a large vacuole, which was presumed to be a globule of fat. These are seen in normal dogs, but are believed to be an indication of some damage to the metabolic process of the cell.

The kidney contained no notable lesions. Some kidneys showed cloudy swelling and others con-

TABLE II.—DOGS INOCULATED WITH MIXED CULTURE NO. 2 AND GIVEN THERAPY AS INDICATED

Dog No.	Age in years	Time of death** postinoculum	General condition	Pathological changes***				Miscellaneous
				Heart	Leg	Liver	Kidney	
A. Penicillin alone after hours								
P		Died 7 d.	Good	+	N			
B. Penicillin (16,000 units) and sodium sulfadiazine 3 hours postinoculum for 7 hours								
P	5	Killed 23 d.	Poor		R			
C. Penicillin (16,000 units) 6 hours postinoculum + 2 dose of sodium sulfadiazine 3 hours postinoculum								
P 14		Killed 20 d.	Good	+	R			
P 5		Killed 10 d.	Fair		R			
P 28		Killed 10 d.	Excellent		R			
P 33		Died 7 d.	Fair		R			Fungus bronchopneumonia
P 44		Killed 10 d.	Good	+	R			
P 145		Died 28 h.	Excellent	+	N	+		Bronchopneumonia
P 45	3	Killed d.	Excellent		R			
P 50		Killed 20 d.	Excellent		R			
P-212	3	Killed 20 d.	Excellent		R			
D. Penicillin (14,000 units) 3 hours postinoculum + 2 dose sodium sulfadiazine 3 hours postinoculum—Ser./A antitoxin 3 hours postinoculum								
AP		Killed 3 d.	Good		R			
AP	5	Killed 23 d.	Excellent		R			
AP-6		Killed 3 d.	Fair		R		+	
AP 7	3	Killed 3 d.	Good		R			
AP		Died h.	Good					Brain stem normal ? Anaphylaxis
AP	3	Killed 3 d.	Fair		R			
AP 17	1	Died 24 h.	Excellent					? Anaphylactic death—Antitoxin
AP 3		Killed d.	Fair		R			
AP 3	3	Killed d.	Fair		R			
AP 33	3	Died 1 d.	Fair		N	+		

¹Doses indicated are amounts per kilogram weight of dog
²—d=days; h=hours.

+, N, changes; + slight changes, moderate changes; + severe changes; R, inoculated site shows signs of recovery; H, slight signs of recovery; K=no recovery.

lained tubules which were filled with a fine granular coagulum. In some the blood vessels were engorged with red corpuscles, but neither necrosis nor hemorrhage as seen.

THE PATHOLOGICAL CHANGES IN TREATED ANIMALS

Most of the treated dogs recovered from the gas gangrene infection and, in general the inoculated site showed remarkable repair of the original severely damaged muscle. Some of the inoculated thighs were practically normal in gross and microscopic appearance. However they showed microscopic changes indicating obvious severe damage earlier in the course of the disease. Microscopically the leg muscles were filled with acute or chronic inflammatory cells, or both. There were numer-

ous fibroblasts, and new dense connective tissue was being laid down. The fibrin and red blood corpuscles had disappeared. The empty network of connective tissue between the original muscle fibers contained large cells which were eosinophilic and contained a single small oval nucleus. Many of these cells had begun to grow to enormous size and developed a striated cytoplasm as well as several nuclei. This appeared to be muscle regeneration or replacement of destroyed muscle by new muscle fibers. Although the inoculated muscles showed marked disintegration edema and areas of necrosis before recovery they were replaced not by masses of scar tissue but by muscle tissue so that in some dogs the muscles assumed a normal appearance. Further studies of this process are being carried out. The muscle fibers which

TABLE III.—DOGS GIVEN THERAPY ALONE WITHOUT INOCULATION BY CLOSTRIDIA

Dog No.	Age in years	General condition	Pathological changes				Miscellaneous
			Heart	Lug	Liver	Kidney	
F 207		Excellent					
F 214		Excellent					

*This study was conducted to show that there is no incompatibility between penicillin and sodium sulfadiazine which could be detected by histological study.

have been partially destroyed by the disease contain more nuclei than are usually seen in normal muscle. These nuclei were also larger than skeletal muscle nuclei.

Frequently the skin overlying the inoculated thigh was necrotic and hung loosely over the thin, atrophic muscles. The latter was cleaned of subcutaneous fascia and all connective tissue coverings. The red muscle shone through a very thin layer of fascia. Each individual muscle lay separate and moved freely.

The heart showed only an occasional area of old necrosis with good organization. Some fragmentation with scattered areas of hyalinization was noted. Those dogs dying in spite of treatment had severe cardiac fragmentation, hyalinization, edema, pallor, loss of striations and marked engorgement of all the blood vessels, especially the arterioles and venules. A few of these animals had a complicating bronchopneumonia. One may postulate that the cardiac damage in these fatalities was a result of the action of the toxin which was formed prior to the institution of adequate therapy since enough growth of the organism had occurred to cause severe necrosis at the inoculated site.

The liver in general was undamaged. The cells all appeared filled with "foam," which apparently was glycogen and fatty compounds. The cell walls, their nuclei, and their size and shape appeared normal. The sinusoids were moderately engorged with red blood corpuscles. Some of the livers had clumps of chronic inflammatory cells and fibroblasts with organization, indicating that damage had been done in the past and that it had been checked.

The kidney showed no significant damage either as a result of the disease or of the therapeutic agents.

The following animals were all inoculated with mixed culture No. 3. They were treated by the use of penicillin, sodium sulfadiazine and antitoxin, as indicated.

1. *Penicillin alone* (Table II—A) One dog was studied. This dog died 7 days after inoculation. It had some cardiac changes and the leg showed healing. Some liver necrosis was present.

2. *Penicillin and sodium sulfadiazine* (Table II—B and C) Ten dogs have been studied. Eight were killed 10 days following inoculation. One dog showed severe fragmentation of the heart muscle. The heart had no changes in the other animals. One had many small areas of necrosis in the liver. One dog died 7 days following inoculation. This animal had numerous masses of fungi in the lungs causing severe bronchopneumonia. The other organs were intact. One dog died 28 hours after inoculation. There was a marked reaction at the site of the inoculation. This dog had severe cardiac and liver damage, and bronchopneumonia. In all of the recovered animals the inoculated sites were well healed and no kidney changes were present.

3. *Penicillin plus sodium sulfadiazine plus antitoxin* (Table II—D) Ten dogs were studied. Seven of the dogs were killed within 12 to 13 days after inoculation. Only 1 of these dogs showed significant cardiac damage. The inoculated sites were well healed and no changes were seen in the other organs. One dog died 10 days after inoculation and it showed severe edema and focal necrosis of the liver. The heart muscle had small areas of hyalinization. The inoculated site had a large abscess.

Two of the dogs died within a few minutes after being given intravenous clostridial antitoxin. An autopsy was done immediately after they stopped breathing and no pulse was felt. The auricles were still contracting feebly indicating that the nerve bundles of the heart were not disturbed. One dog had moderate cardiac changes. There were no changes in any of the other organs and no thrombi were seen. The lungs had tiny emphysematous blebs throughout. Thus, death was probably due to anaphylactoid shock.

4. *Sodium sulfadiazine three hours after inoculation (one dose) plus antitoxin twelve hours after inoculation* (Table IV—A) Nine dogs were studied, all but 3 were killed after 10 days. These showed that the inoculated sites had received severe damage but were being repaired. The disease was under control. The heart showed only slight changes in 2 dogs. Three dogs had small foci of necrosis in the liver.

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TABLE IV—DOGS INOCULATED WITH MIXED CULTURE NO. 2 AND GIVEN THERAPY AS INDICATED

Dog No.	Age in years	Time of death** postinoculum	General condition	Pathological changes***				Miscellaneous	
				Heart	Leg	Liver	Kidney		
A Sodium sulfadiazine (dose) after 3 hours and anthrax after 6 cc/k in 8 hours									
A-68		Killed d.	Poor						
A-78		Killed d.	Poor						
A-79		Killed d.	Excellent						
A-90	7	Died 9 d.	Good		R				
A-93		Killed 13 d.	Poor	S	R				
A-94		Killed d.	Good		R				
A-96		Died 6 d.	Poor		R				
A-97		Killed d.	Fair		N				
A-98	10	Killed d.	Fair		R				Severe bronchopneumonia
B Sodium sulfadiazine after 7 hours and anthrax after 6 cc/k in 8 hours									
A-107		Killed 14 d.	Good		R				
A-108		Killed d.	Fair		R				
A-109		Killed d.	Excellent		R				
A-110		Killed d.	Good		R				Acute endometritis
A-111		Died 4 d.	Excellent		R				
A-112	3	Killed 3 d.	Good		H				
A-113	7	Killed 3 d.	Good		R				
A-114		Killed d.	Good		H				
A-115		Killed 1 d.	Excellent		R				
A-116		Killed d.	Excellent		R				
A-117		Killed d.	Excellent		R				
A-118		Killed d.	Excellent		R				Generalized early lymphocytosis
A-119		Died 7 d.	Good	S	H				Brain stem, spinal fluid—

Doses indicated are amounts per kilogram weight of dog.

*** Mild changes slight changes, moderate changes; S, severe changes; R, isolated abscesses.

Postmortem changes No gross changes Lungs normal

Brain stem, spinal fluid—

Doses indicated are amounts per kilogram weight of dog.

0, no recovery; S, slight changes; H, moderate changes; E, severe changes; R, inoculated site shows signs of recovery; H, slight signs of recovery; The liver in most cases was engorged by red blood corpuscles.

Two of these 9 dogs died after 9 and 6 days, respectively. These also showed some recovery of the inoculated site but one revealed severe cardiac damage, and the other dog had bronchopneumonia. Both had moderate damage in the liver 5 Sodium sulfadiazine three hours after inoculation for seventy-two hours plus antitoxin twelve hours after inoculation (Table IV—B). Thirteen of these dogs were studied. Only 1 showed significant cardiac damage. All of the animals showed good healing and recovery at the inoculated sites. No significant pathological changes were seen in the other organs.

Three died in 4, 7 and 10 days, respectively. Two had severe cardiac damage and some liver damage. The sites of inoculation were healing well.

SUMMARY

In general, the untreated dogs receiving a mixed culture of gas gangrene organisms (No. 2) showed more severe damage than did those animals receiving a single pure culture of one of the clostridia studied. We were unable to determine any difference in degree of damage caused by the various pure cultures of the individual clostridia or the infection was severe and that extensive damage was always produced at the site of inoculum. All but 3 of the control dogs showed some cardiac damage. Liver damage was considerable. The brain stem and spinal fluid were studied in 4 dogs with negative results. The other organs, including the kidneys were undamaged. Four of the dogs had bronchopneumonia.

The untreated animals showed excellent recovery of the inoculated site. In most instances cardiac damage was prevented. The liver received only minor injury in most dogs. The few animals dying as a result of the infection despite therapeutic measures revealed cardiac damage and complications. The kidneys were unaltered by disease or therapy. Two dogs died an anaphylactoid death presumably from antitoxin therapy.

Most authorities agree that death in clostridial infections is toxic in nature. Our experimental studies would bear this out. The mechanism of death is not agreed upon by the various writers. Our studies indicate that, with the exception of the local site of the infection, the heart and liver (in the order named) are the organs most frequently and most severely involved. The rôle of liver damage as a cause of death in our animals cannot be fully evaluated as blood chemistry studies were not done. No definite kidney damage could be found as a result of the disease or the treatment.

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PRIMARY CARCINOMA OF THE EXTREMITY

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A STUDY of primary carcinoma of the extremity seen at the Barnard Free Skin and Cancer Hospital from 1925 to 1930 has been made, and the results of this study are presented here.

The series comprises 214 cases, which is 4 per cent of an estimated 5,000 cases of skin cancer recorded at this clinic during this period. Of the 214 cases, in only 15 per cent was the lower extremity affected as compared with 85 per cent for the upper extremity. This ratio is comparable to that found by other observers. Of the 182 cases of upper extremity carcinoma, 132 occurred in males and 50 in females, whereas in the lower extremity there were 23 cases in males and 9 in females. The lesion affected the right extremity in 94 cases as compared with the left in 88 cases; the right lower extremity in 15 cases and the left lower extremity in 17 cases. The lesion of the upper extremity is definitely one of advanced age as the maximum incidence occurred in the group of patients 70 years of age or older. This is in contrast to the maximum incidence of cancer elsewhere (on the skin) as then the maximum incidence is found to be in an earlier age group. The incidence of lower extremity carcinoma is greatest in the group 50 to 60 years of age.

In the entire series there was but 1 negro who had a primary carcinoma of the extremity—a squamous cell lesion of the leg. This 1 case is not a true indication of the frequency of the disease in negroes in general as negroes comprised less than 5 per cent of the patients seen in this clinic. There is some indication that the incidence of skin cancer on unexposed portions of the bodies of negroes does not differ remarkably from the incidence on unexposed parts of whites.

On the upper extremity, as in other series, the preponderance of lesions occurred on the dorsum of the hand. There were 150 lesions of the hand, 14 of the arm and 9 of the fingers. Four of the lower extremity lesions occurred on the toes, 6 on the foot and 22 on the leg.

In general the various precancerous conditions which have been known to precede cutaneous carcinomas appear as well to extremity carcinoma. A

classification of etiological factors has been offered by Mason as follows:

- I Carcinomas arising in connection with trauma or irritation
 - a. Irradiation
 1. Ray
 2. Radium
 3. Solar (such as exemplified by senile keratoses, keratoses in sailors, farmers, etc.)
 - b. Chemical irritation external (e.g. tar, anilin pitch, etc.)
 - c. Internal (arsenical)
 - d. Chronic mechanical irritation
 - e. Scar tissue irritation (burn scar especially)
 - f. Irritation from a single trauma or ch. oil infection, syphilitic ulcer, varicose ulcer, etc.
- II Carcinoma arising in some previous skin tumor
- III Carcinoma arising from normal skin

In this clinic, serving largely a rural population, a great many cancers have occurred as a result of exposure to solar radiation, for example in farmers or patients presenting sailor's skin. Of the 182 patients with upper extremity lesions, 72 gave a history of being farmers or had been engaged in outdoor occupations, 50 exhibited or gave a history of pre-existing keratoses and 50 had already either experienced or subsequently developed another cutaneous cancer. This high incidence of multiple lesions has not been noted in other studies of the subject.

The histories studied gave few clues to other etiological factors. No patient developed carcinoma as a result of x radiation, a relatively frequent etiological factor in many clinics. One patient gave a brief history of working with tar. Five patients gave a history of a single trauma as the etiological factor. On the upper extremity, in 2 cases carcinoma developed in old scars and on the lower extremity, in 4 cases carcinoma occurred in old scars, one of them a burn scar. No definite mechanical factor as a possible cause of the lesion was found in this series; neither was chronic irritation an important factor. In none of the cases was carcinoma found in old osteomyelitis sinuses, sites occasionally reported by other observers. Arsenical keratosis has been considered as an etiological factor, 14 of 312 cases of extremity carcinoma reported by Taylor, Nathanson and Shaw were preceded by arsenical keratoses. Although it is not an uncommon finding in other clinics, epidermal carcinoma developing on the basis of arsenical keratosis has not been seen either

From the service of D. W. E. Leighton, Barnard Free Skin and Cancer Hospital. Dr. Clarke is trainee of National Cancer Institute.

in the surgical or dermatological departments of this hospital. There was but 1 case of cutaneous cancer which developed in a lupus scar but this cancer was not of the extremity. Lupus as a precursor of cancer is also a more frequent finding in other clinics. Mundelein in a series of 2,557 cases of lupus, reported 83 cases of cancer. The development of cancer on a pre-existing benign lesion was not definitely demonstrated in any of our cases, but in 4 patients the very long history (20 years) suggested this etiological factor.

The diagnosing of cutaneous carcinoma offered little difficulty. Almost invariably it was made on examination of patient. The presence of a malignant lesion developing in a chronic ulcer or old sinus tract was not so readily determined. In some instances an infected epithelioma closely resembled a granuloma. In such cases a biopsy was made to establish the diagnosis.

The malignant lesion of the extremity is usually a squamous cell carcinoma. There were 163 such lesions of the upper extremity as compared with 18 basal cell lesions. There were only 3 basal cell tumors of the lower extremity and 18 squamous cell lesions. This ratio is not at variance with that found by other observers. The basal cell lesions developed at an earlier age than did the squamous cell tumors. There was one sweat gland carcinoma in this series and one basosquamous cell lesion. The great majority of the squamous cell tumors have been of low grade malignancy. In this study, there were but 4 lesions which could be classified as Broders' group III and one in the group IV classification. All other squamous cell lesions could be classified in either group I or group II. Low grade malignancy has been found characteristic of carcinoma of the extremity in other reports: 97 per cent were group I or II in DeBell and Stevenson's series.

The treatment of all but 7 of the local lesions was surgical and consisted of either local excision or amputation, depending on the extent of involvement. In general, the decision to perform an amputation rested upon the amount of fixation of the lesion. Even though there was obvious regional lymph node involvement amputation was not done if the local lesion was not fixed. Extensive superficial lesions have been locally excised with good results, and on several occasions, lesions which were only slightly fixed to the underlying structures, were locally excised with resulting cure. These latter types of lesions were excised with cautery. It was also the practice to use the cautery for sloughing, necrotic, infected, ulcerated lesions. If a defect was not amenable to immediate closure, the defect was covered with a split

graft, immediately if the lesion was clean or after a suitable bed of granulations had been established when it had been necessary to resort to cautery. There have been only 6 local recurrences following local excision in this series. One fatal outcome followed local recurrence, and in 1 case the second operative effort consisted of an amputation. Five of the local lesions were treated by radium with 3 local recurrences resulting, and 1 lesion treated with x-ray promptly recurred. With more adequate dosage and present day methods of radiation, however, x radiation should give good results in superficial lesions.

The criterion for amputation, with rare exception, was fixation of the lesion. The site of amputation, when it was required, was determined by the requirements of satisfactory margin and good function. If there was clinical involvement of the epitrochlear or popliteal space, the chosen site of amputation was above the elbow or the knee. In 2 patients who had extensive axillary involvement, with fixed nodes, shoulder girdle amputations were done. One of these patients died after operation, the other died in 1 year of carcinomatosis.

The proper handling of the lymphatic drainage areas of the extremities is the most perplexing problem offered in connection with the treatment of carcinoma of the extremity. In general, it may be said that in this series lymph node dissections were not done unless there were clinically involved nodes.

In this series the analysis of the lymph node involvement is as follows: in 24 patients of 136 with upper extremity lesions which could be followed 4 years or more, the lymph nodes were noted as being 2 centimeters or larger when first seen. In 15 patients they were between 1 and 2 centimeters and in the remaining 107 they were either not recorded as being palpable, or were less than 1 centimeter in size. Of this latter group, 6 patients subsequently developed suspicious axillary nodes, and of these 6, 3 patients subsequently died of the disease. Two of these 3 patients were not faithful in their check-up visits at the clinic, and when they finally presented themselves for operation, their nodes were between 5 and 6 centimeters in the greatest dimension and were partially fixed. The third case had a prompt axillary dissection when it was noted that the axillary nodes were enlarging. He had a Broders' group III lesion and died of generalized carcinomatosis in 2 years. In the group with nodes 1 to 2 centimeters in size there were 5 patients on whom axillary dissections were done. Only 1 of these 5 had positive nodes, and in this patient the nodes were described as

stony hard and were very suspicious clinically. In the third group 8 were subjected to axillary dissection and of these 7 had positive nodes. In 2 axillary dissection was deferred to a second stage because of debilitation of the patient, and subsequent to the removal of the primary lesion the nodes subsided and have remained nonsuspicious. One refused operation 1 was considered in operable and 2 had extensive fixed nodes and were subjected to shoulder girdle amputation. Of the entire group only 6 patients who were thought to have no nodal involvement when first seen, subsequently developed nodes which were thought to be clinically positive and of this group only 4 actually proved positive. Three of these 4 as pointed out, died of the disease.

Of the group of lower extremity carcinoma (32 cases) 5 patients had nodes 2 centimeters or larger when first seen 3 had nodes between 1 to 2 centimeters, and the remainder had nodes 1 centimeter or less. Four of the 5 with large nodes were subjected to inguinal dissection, and all proved to have positive nodes. The nodes of the fifth patient subsided after removal of the local lesion. One patient with nodes between 1 and 2 centimeters was subjected to an inguinal dissection which revealed positive nodes. Two patients with stony hard 1 centimeter nodes had inguinal dissections but their nodes were negative. An expectant attitude was adopted regarding the remainder of whom one patient subsequently developed clinically positive nodes. This patient deferred surgery for 9 months after it was advised and died after operation of hemorrhage. At operation the nodes had been found to be matted and firmly attached to the femoral vessels.

It may be said then that in this series, 4 patients died who might have been saved by doing a 'prophylactic' node dissection. This statement should be qualified by the information that 3 of the 4 patients were unco-operative in returning to the clinic for check up so that surgery was deferred beyond the time when it would ordinarily be recommended.

No iron clad rule should be adopted in regard to the treatment of axillary or inguinal nodes. For most patients the concept of performing axillary node dissections only when enlarging or persistently enlarged nodes (i. e. nodes which remain enlarged after the removal of the primary lesion) are present would seem to be a good one. The grade size duration precursor of the lesion and the age of the patient are factors however that should be considered when making a decision regarding the treatment of the lymphatic drainage areas. It would be reasonable for example to per-

form an axillary dissection on a relatively young individual with a fixed grade III lesion of his hand even though no nodes were palpable. It is also reasonable to perform axillary dissections regardless of the clinical state of the axilla, if there is epitrochlear involvement.

A more radical attitude may be adopted regarding the treatment of involvement of the inguinal nodes. There appear to be good reasons for this. First the percentage of inguinal lymph node involvement in our series was high as compared to that of the upper extremity. Six of the 22 cases which we were able to follow satisfactorily had positive inguinal lymph node involvement or subsequently developed it. Second the prognosis, if inguinal lymph nodes are involved is very poor as demonstrated in the series of Taylor, Nathanson, and Shaw and in our own series. Third lower extremity carcinoma occurs in a younger age group and more radical attempts to eradicate it are justified.

Many surgeons have adopted a conservative attitude in regard to the treatment of lymph node involvement, i. e. they advise node dissection for persistently palpable nodes. Still others present figures which are not quite so convincing as to the value of the conservative attitude. Taylor, Nathanson and Shaw report that axillary metastases subsequently developed in 21 per cent of 154 cases with nodes less than 1 centimeter when first seen. Pack has stated that the 24 per cent of patients admitted to the Memorial Hospital with epidermoid cancer of the extremity, without evidence of regional lymph node involvement subsequently developed lymph node metastases. It must be remembered that the series at the Barnard Free Skin and Cancer Hospital with the exceptions noted is composed of malignant lesions which had as precursors either a skin or senile keratosis or the lesions developed upon previously normal skin. There is some indication that such carcinomas of the extremity that is, carcinomas which have as precursors either a skin or senile keratosis, are less malignant than those which develop on certain other etiological bases for example in Taylor, Nathanson and Shaw's series, 30 per cent of the cases developing in burn scars, 30 per cent of those developing in varicose ulcers (a comparatively rare site of extremity carcinoma) and 21 per cent of lesions developing as a result of arsenical keratosis exhibited lymph node metastasis. Handley advises radical removal of lymph nodes in all cases of roentgen carcinoma so frequently did he find that lymph node metastasis developed from roentgen carcinoma.

The prognosis of the disease, as shown in this series, has been good in regard to the upper extremity but less favorable in regard to the lower extremity. Of our 182 upper extremity cases, 9 died of the disease, 112 were followed 5 years or more without evidence of the disease, 15 were followed 4 years without evidence of disease, and 46 patients could not be followed. In the followed group of 136 cases the survival rate was 93 per cent. The prognosis, as would be expected, was less favorable if there was lymph node involvement. Of 11 axillary dissections revealing positive nodes, 3 died of the disease, 6 remained well, 2 were not followed—a survival rate of 66 per cent excluding the cases that could not be followed.

In the lower extremities, 10 cases could not be followed. Of the 22 remaining 6 died of the disease, 2 were free from disease 4 years after treatment and 14 were well 5 years or more after treatment. The survival rate was 70 per cent. Of those with positive inguinal nodes who had inguinal dissection, only 1 of the 5 patients who could be followed survived.

There are few published 5 year end result figures for extremity carcinoma. Other reports in general indicate a higher mortality which could be estimated at double that which we have reported with a similar ratio between the degree of malignancy of the upper and lower extremity lesions. This difference could possibly be ascribed to varying etiological factors, as the treatment in the larger reported series has not been materially different from the treatment at this clinic. The effect of lymph node involvement on prognosis is similar in other series to that reported here. Pack reports 17 axillary dissections revealing positive nodes, with 35 per cent mortality and 7 inguinal dissections with 38 per cent mortality from the

disease, with 2 patients not followed for 5 years. Taylor, Nathanson, and Shaw report 21 axillary dissections with positive nodes, with only 9 cures, and of 14 patients with positive inguinal nodes, only 2 were known to have survived.

CONCLUSIONS

1. Primary carcinoma of the upper extremity is of considerably more frequent occurrence than primary carcinoma of the lower extremity. On the upper extremity the maximum incidence is in a later age group.
2. Squamous cell carcinoma on the extremity occurs approximately eight times more frequently than does basal cell carcinoma. The lesion is characteristically of low grade malignancy.
3. The treatment of superficial or slightly fixed lesions is local excision. Amputation is indicated for extensive and fixed lesions.
4. Regional lymph node dissection is always indicated in the presence of persistently enlarged or enlarging nodes. In some instances, lymph node dissection may be indicated in the absence of palpable nodes.

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EDITORIALS

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THE ULCER CARCINOMA PROBLEM OF THE STOMACH

BECAUSE many surgeons have shared an indomitable conviction that carcinoma of the stomach is relatively curable by early resection cures in the terms of living and well two five ten and even twenty years following operation have been reported in increasing volume from many clinics. This accomplishment and the prospect of increased salvage in the future are the result of two factors: a progressive reduction in operative mortality and a progressive increase in the number of early resectable cases. The former is for the most part an accomplished fact with surgeons of large experience in this type of surgery. Thus until some form of treatment which offers more than surgical resection is forthcoming progress will result principally from contributions which will serve to shorten the interval between the inception of the neoplasm and the recognition of its presence. By the word inception it is intended to imply the not improbable develop-

ment of a means by which the presence of neoplastic tissue can be detected before it gives rise to symptoms. At present progress will depend upon factors which will shorten the interval between the onset of symptoms and the recognition of the disease. These factors concern mainly medical and lay education. Compared to this potential source of benefit the salvage to be derived from such future contributions as will effect a further reduction of operative mortality is insignificant.

The delay in the recognition of carcinoma of the stomach has been attributed much too generously to the patient's indifference to his symptoms and reluctance to consult a physician. Unfortunately the evidence in the majority of instances also incriminates the medical profession. This is attributable to certain misconceptions regarding the disease. It is not generally appreciated that despite every available means of diagnosis it is impossible in an astonishingly large percentage of cases to differentiate early carcinoma of the stomach from benign gastric ulcer. This fact and its importance in respect to early diagnosis and treatment has been brought out in the singularly important publications of Allen and Welch¹ and of Walters Gray and Priestley. From a study of two thousand four hundred and sixty nine cases of carcinoma of the stomach at the Mayo Clinic Walters Gray and Priestley² found that thirty seven per cent of the patients who had operable carcinomas of the stomach and twenty five per cent of patients with inoperable lesions gave histories that were typical of benign ulcer and further more the distressing fact that eighty per cent of the patients with carcinoma of the stomach

1. Surg. Gynec. & Obst. 44: 16, 1927.
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THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

THE present edition of Osler¹ brings up to date a textbook which was designed for the use of practitioners and students and has gone through fifteen editions since 1892. The present author under whose direction three editions have been published has lived up to the Oslerian tradition by presenting from personal observation clinical descriptions of most diseases. Some 780 medical entities are grouped in an orderly index and detailed within the 498 pages of this book.

Notable among the additions in this volume is a chapter on aviation medicine dealing with the effects of high altitude, high speed, cold and wind on the human organism. The inclusion of such uncommon diseases as ornithosis and phlebotomus fever shows the importance of domestic fowl and insects as vectors in the dissemination of virus infections.

Sulfonamides are given more consideration in the treatment of pyogenic infections. Unfortunately this book went to press before penicillin became available to the medical profession consequently the information on this drug is incomplete.

No textbook in medicine is written for a larger group of readers. The practitioners will appreciate this work for its uniformity and high quality and will value the carefully selected and informative references. As a textbook it would have more appeal to the student of medicine if less effort were directed at encyclopedic completeness and more illustrations were used. It can be well recommended to all.

HOWARD B. CARROLL.

IN his book *Vascular Responses in the Extremities of Man in Health and Disease*² Dr Abramson has uniquely brought together physiological concepts and methods of examination of the circulation in the extremities in health and disease and has evaluated very fairly both methods and results. His approach to the problem is stimulating, interesting, succinct, and the subject matter is so clearly stated that it is easy for the student and clinician to grasp. The quantitative methods of examination are described in detail. It stresses particularly the venous occlusion plethysmographic method of studying the rate of peripheral blood flow yet is fair in stating the necessary precautions for accuracy and the factors limiting its usefulness.

¹THE PRINCIPLES OF PRACTICE OF MEDICINE. Originally written by Sir William Osler, Bart. M.D. F.R.C.P., F.R.S. Translated for the Use of Practitioners and Students of Medicine. By Henry A. Christy, A.M., M.D., LL.D. (Hon.) B.Sc. Hon. F.R.C.P. (Cant.), F.A.C.P. 9th ed. New York and London: D. Appleton-Century Co., Inc., 1944.
²A VASCULAR RESPONSE IN THE EXTREMITIES OF MAN. By JACOB HOFFMAN. By David I. Abramson, M.D. F.A.C.P. Chicago, Ill.: The University of Chicago Press, 1944.

The chapters devoted to anatomy, physiology and the nervous control of blood vessels contain epitomized essentials which make them ready references for student and collateral reading. His summary of quantitative procedures in the study of blood vessels and the rate of peripheral blood flow is useful and from a practical standpoint in general use. The reviewer is particularly in accord with his recommendation of peripheral nerve block for practical purposes as compared to lumbar and dorsal sympathetic block in studying temperature responses of the extremities in occlusive and spastic vascular disease. Peripheral nerve block is simple and without danger. Spinal anesthesia, lumbar and dorsal sympathetic and brachial plexus novocaine infiltrations are technically more difficult, anesthesia less often completely accomplished, fraught with more accidents and the added information rarely justifies the use of the more complicated procedures.

He has considered the physiological function of ingestion of food, menses, gestation, an x-ray, and effect upon peripheral blood flow interestingly and quotes other experiences extensively before stating his conclusions.

Pharmacologic agents, hormones, insulin, histamine, acetylcholine, prostigmine, neosynephrin, picrodrol, picrodine, tobacco, ergotamine tartrate, reserpine and angiotensin and anesthetic agents are considered, and the literature is date reviewed.

Blood flow in abnormal states including metabolic, systemic, blood, cardiac and neurologic disorders are briefly but completely discussed combining their physiological interpretation with their clinical manifestations.

The functional and organic vascular disease of the arteries and veins and the evaluation of methods used in their treatment are discussed in keeping with the latest clinical conceptions of pathology and therapy.

The style of the book is engaging, simple, compact and its ease of reading is gratifying for its contents are such that they might have been technically confusing.

The references at the end of each chapter are extensive. The book is a great source of material for students and clinicians interested in this problem.

BRYCE L. CREW SMITH.

THE book entitled *Female Endocrinology*³ by Jacob Hoffman is a useful reference work of physiological and clinical literature in endocrinology.

FEMALE ENDOCRINOLOGY. Inclusive Sections of the Male. By JACOB HOFFMAN, A.B. M.D. Philadelphia and London: W. B. Saunders Co., 1944.

Approximately half of the book is taken up with a review of endocrine physiology according to organs while the second half is concerned with clinical endocrinopathy. A third section is devoted to laboratory methods and results. A bibliography of references is appended to each chapter of each section.

The author's personal testimony on endocrine treatment is to be commended for its honesty and conservatism. When quoting the literature the author has a tendency to report the claims of older papers. Such and such a writer stated that this or that endocrine treatment was successful. In this way many uncorroborated claims are perpetuated. It is apparent from a historical point of view that many therapeutic trials are reported in the course of medical history which later are found to be completely irrelevant when the true treatment is discovered. Textbooks and reference works have a tendency to cherish these abortions and preserve them much to the confusion of the uninformed reader and to the indefinite extension of bibliographies. Such compilations should be confined to medical history.

The reviewer has the impression that the great fields of growth and maturation have been neglected. Adolescence is covered in five pages and no systematic discussion of growth appears in any section. In the discussion of obesity the psychosomatic aspect of this condition is not emphasized. The estrogenic control of menopausal symptoms seems to the reviewer to be unnecessarily discounted. In certain cases it is definitely specific and remarkably effective.

In general one might say that such a book does accumulate much valuable material and gives many references which may or may not be valuable, that it fails to give practical direction to the clinician since the discussion usually ends in a nebulous argument pro and con and that neither endocrinology nor medical gynecology receive adequate presentation.

PAGE STARR.

THE excellent book *Industrial Ophthalmology* by Hedwig Kuhn will be of great value to ophthalmologists engaging in industrial work. It is the first comprehensive treatise that has been published dealing with industrial ophthalmology as a special field. In this book the author attempts to correlate the essential information relating to the visual problems of the worker and his job.

A whole chapter is devoted to visual testing in industry. It starts with the problem of job analysis which is the appraisal of a specific job as it applies to the demands made upon the eye during the performance of the work. From the standpoint of examination the test may be divided into pre-employment, periodic checks and general surveys. The standard basic visual data needed are visual acuity for distance and near with and without glasses

stereopsis, muscle balance and color appreciation.

The correction of visual defects for the job is discussed at some length and here the author shows the value of expert advice in increasing the production and the prevention of accidents.

Dr. Albert Snell has contributed an excellent chapter on industrial eye injuries caused by solid bodies. This chapter includes a description and classification of eye injuries together with their treatment and complications. The chapter on eye protection lists the types of goggles available and discusses a goggle program which even includes fitting and servicing by a plant optician.

Welding, flash conjunctivitis and epidemic keratoconjunctivitis are discussed in the chapter on recent developments as they are related to industrial eye problems.

The appendix is devoted to toxic hazards with a glossary of terms. There is also an outline for an industrial eye program and the appraisal of loss of visual efficiency as approved by the Section in Ophthalmology of the American Medical Association in June 1940, is added. The book contains many excellent illustrations with several color plates.

IRVING PETERSON

THE second edition of a volume published a year ago under the title of *Gynecology and Fetal Endocrinology*, now appears as a *Textbook of Gynecology* actually it is more than that. It is an expansion into an admirable textbook for medical students and general practitioners. While only a few chapters have been added, they represent a real advance. One is a chapter on embryology of the female generative tract which consolidates considerable material which was scattered throughout the original work. The second on common disorders of the female urinary organs is written by Dr. Houston S. Everett. It is well done, but could have been more inclusive and it is hoped that a future edition will remedy this incompleteness.

Novak has redistributed the material in this text to good advantage. The space devoted to anatomy, history, taking and examination methods has been reduced and the space gained has been excellently devoted to pathology, endocrinology and the so called functional disorders. There is a profusion of illustration, many of them in color, a factor which helps to make the text valuable. Special mention should be made of the chapters dealing with normal and abnormal menstruation, the menopause, sterility and the problems of sex life. They are true reflections of the sanity and common sense which have always characterized therapy as recommended and practiced by the author.

All these assets when summed up make a complete picture. The textbook is most heartily recommended to those for whom the author has written it viz. medical students and general practitioners.

PATRICK R. RICE

AN excellent, up to date small, compact textbook which contains the most recent knowledge pertaining to tuberculosis of the ear, nose, and throat, including the larynx, trachea and bronchi has been written by Dr. Bliverson.

The various phases of tuberculosis are described and discussed completely as to diagnosis, prognosis, pathology and treatment. To enhance the discussion, there are many tables of statistics, abundant case histories, and a goodly number of very excellent illustrations all of which are of great assistance. The author has gone to great length carefully to describe the many forms of therapeutic measures which have

been advocated, those which have survived and those which have failed.

In discussing bronchoscopy in tuberculous patients the author from his vast experience has found that certain patients are very definitely improved by such a procedure while others suffer detrimental effects. To overcome this harmful result the author has developed a special technique described in detail.

The chapter discussing outtuberculous diseases of the ear, nose, and throat portrays the various types of lesions which may occur in a tuberculous patient. Thus the reader is cautioned to be on the look-out for such lesions even though the patient is a tuberculous one.

This book is most enlightening and refreshing.

LION F. McBRIDE

TUBERCULOSIS OF THE EAR, NOSE, AND THROAT, INCLUDING THE LARYNX, THE TRACHEA, AND THE BRONCHI. By Morris C. Myerson, M.D. Springfield, Ill. and Baltimore, Md. Charles C. Thomas, 1944.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

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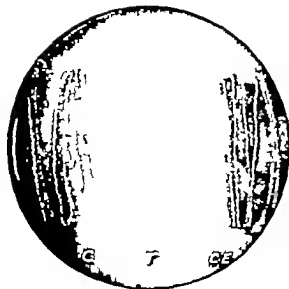


Fig. 7. Subculture of colon bacillus after treatment with canavalin. C control, same as T but untreated by canavalin. CE, control, original culture of colon bacillus.

flavin are used to produce *in vitro* a supply of co-enzyme. This co-enzyme is called by me "vitatropin" and has the physical characteristics usually possessed by a co-enzyme—thermostability, filterability, and the property of being precipitated from a watery solution by an organic solvent. It is an interesting fact that both enzyme and co-enzyme have been found by me to be present in normal blood. Quantitative tests for content of both these substances in the blood have been devised.

The oxidative canavalin reaction with bacteria as a substrate takes place with equal ease when the medium contains milk or blood as when the medium is a watery solution. The hypothetical importance of this is that the blood has been shown to contain catalase-like substances which inhibit enzyme reaction. It can be assumed therefore that the oxidative reaction in question is not inhibited by the catalase-like substance in the blood. Members of both gram-negative and gram-positive groups of bacteria are oxidized by canavalin, although gram-positive seem to be more susceptible to its action (Fig. 3).

Action of the enzyme portion of canavalin does not take place unless the co-enzyme is present. Since the co-enzyme (vitatropin) is normally present in blood serum, the enzyme

will always give some reaction in the presence of blood and a suitable substrate.

The apparatus used for determining enzyme action is a modified Warburg apparatus. This enables one to measure in millimeters positive and negative pressure in a glass capillary U tube which is connected to a closed system where the enzymatic action occurs. Mechanical controls provide constant temperature and agitation. Brodie's solution is used in the apparatus as the labile liquid.

PREPARATION OF CANAVALIN

Soy bean or jack bean flour is extracted by a mixture of water and an organic solvent, such as alcohol. A clear supernatant fluid is separated by centrifugation, precipitated by acetone, and the supernatant fluid again recovered by centrifugation. A solution of a heavy metal salt is added to this supernatant fluid. The enzyme forms, hypothetically, a heavy metal enzyme combination. The metallic portion of the combination is removed in the usual way as an insoluble precipitate, leaving the enzyme in solution. To this enzyme solution is added a solution of vitatropin (co-enzyme). The co-enzyme portion has been previously discussed by me as inhibitory substance and OBT. It has now been given the name vitatropin. Vitatropin is extracted from a mixture of a cellular tissue and thiamin chloride which has been allowed to stand for a week with frequent shaking and daily beating for 1 hour at 70 degrees C. After this time it is absorbed on insoluble barium sulfate, and eluted with a weak ammonia solution, from which it is crystallized. The method of preparation of vitatropin is entirely empirical. Canavalin is prepared by mixing the enzyme and co-enzyme solutions. The optimum proportions of enzyme solution to co-enzyme solution is as yet not determined.

IN VITRO STUDIES OF CANAVALIN

An action curve of a given batch of canavalin was plotted (Fig. 4). The points determined were four. The abscissae represent amounts of canavalin solution in cubic millimeters as transposed to linear measurements, the ordinates the height of negative pressure in cubic millimeters of Brodie's solution (trans-



Fig. 2. a, *Staphylococcus aureus* after treatment with canavalin. C Control, same as T without treatment with canavalin. C.E. Control, original culture of *staphylococcus aureus*. b, *Colon bacillus*. T Subculture of *colon bacillus* after treatment with canavalin. C Control, same as T without treatment with canavalin. C.E., Control, original culture of *colon bacillus*.

posed of course to linear millimeter measurements) In order to determine death point cultures of the reacting media were made at each point after completion of enzyme action The points determined were

Canavalin solution	Oxygen uptake
0.010 c.c.	35.0 mm.
0.030 c.c.	60.0 mm.
0.050 c.c.	95.0 mm.
0.00 c.c.	140.0 mm.

The factors of the enzyme reaction were 0.2 cubic centimeter of *colon bacillus* emulsion the washed emulsion containing nine billion living organisms per cubic centimeter 0.5 cubic centimeter of phosphate buffer (pH 7.8) water sufficient to make a total volume of 2.5 cubic centimeters Canavalin solution in amounts stated above Total volume of instrument (closed over all) 15.0 cubic centimeters The instrument used was a modified Warburg

The conclusion was that the minimum quantity of canavalin solution necessary to cause death of bacteria in the factors used was that amount which caused 60.0 millimeters of oxygen uptake That is, death of *colon bacilli* occurred only at the last 3 points plotted on the curve namely 60.0, 95.0 and 140.0 while the cultures taken at point No. 1 showed growth According to this quantitative method it has

been possible to prepare canavalin of ascertained killing dosage

It was considered desirable to compare the bactericidal power and oxygen uptake of canavalin *in vitro* with other agents which might be similar in action For this purpose sulfadiazine and penicillin were selected It was found to be impossible however to make such a comparison since sulfadiazine produces no oxygen uptake with either bacteria or polysaccharides such as starch penicillin in great concentration produces a slight oxygen uptake when used against bacteria with vitatropin as a co-enzyme but in great dilution shows no reaction If penicillin depended upon oxidation of bacteria for its evident beneficent action one would expect some oxygen uptake in high dilution of penicillin A weak solution of penicillin in an enzyme reaction chamber containing only bacteria emulsions and buffer solution was however negative for oxygen uptake

Strangely enough while sulfadiazine gave no evidence of polysaccharide oxidation when used alone with polysaccharides there was marked stimulation of canavalin oxidation by very small quantities of sulfadiazine e.g. — 0.001 milligram of sulfadiazine in a total volume of 2.5 cubic centimeters increased the oxygen uptake of canavalin from 62.0 milli

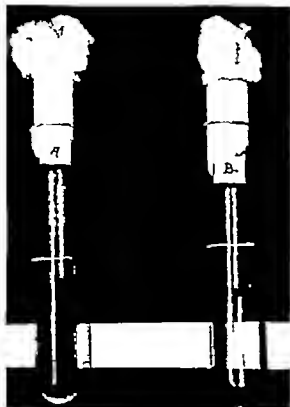


Fig. 3. Subcultures of emulsions of *Staphylococcus aureus* and colon bacillus, showing death of *Staphylococcus aureus* after treatment with canavalin. A, Colon bacillus culture (growth) B *Staphylococcus aureus* (death)

meters to 150.0 millimeters of partial vacuum in the reacting chamber that is more than 100 per cent

RESULTS OF CLINICAL USE

Canavalin before being injected into patients was of course injected in large dosage into both animals and human subjects. There was no toxic effect

CASE 1. M. R. aged 9 years with diagnosis of lobar pneumonia, type undetermined was admitted to hospital January 23, 1944 with a temperature of 103 degrees F. Canavalin was administered with spectacular results. Temperature dropped from 103.5 degrees F. normal in 1 hour and remained normal. The patient was discharged in good condition.

CASE 2. J. T. aged 38 years with diagnosis of lobar pneumonia pneumococcus type IV was admitted to hospital January 24, 1944, with temperature of 103.3 degrees F. Canavalin was administered with drop in temperature in 24 hours to 100 degrees. Patient was discharged in good condition.

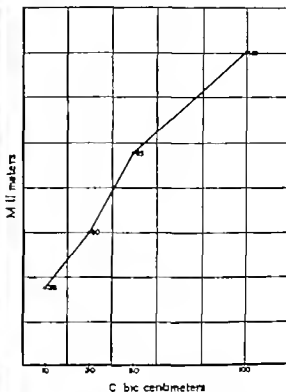


Fig. 4. Action curve of batch of canavalin (Each space represents 1)

CASE 3. C. S. aged 9 years with diagnosis of lobar pneumonia, pneumococcus type XXXIII was admitted to hospital March 27, 1944, with a temperature of 103 degrees F. Canavalin was administered and there was a spectacular drop in temperature to normal. Patient was discharged in good condition.

CASE 4. E. H. aged 55 years, with diagnosis of lobar pneumonia, pneumococcus type V was admitted to hospital March 3, 1944 with a temperature of 104 degrees F. After treatment with canavalin the temperature dropped to 99 degrees. Next day the patient had a chill with involvement of other lung. Canavalin was again administered and the temperature dropped from 100.5 to 100.3 degrees. The patient seemed to be improving when he suddenly died, probably a sudden cardiac failure.

CASE 5. A. O. aged 57 years, with diagnosis of lobar pneumonia pneumococcus type I, unresolved, was admitted to the hospital December 2, 1943, with a temperature of 103 degrees F. Patient was started on sulfadiazine the temperature reached normal in 3 days. The patient continued in good condition for 4 days and then began to have a fever from 99 to 100 degrees F. Sulfadiazine was doubled in dosage, producing a blood level of 17.9 milligrams per cent. There followed a slow decrease of fever to normal. Sulfadiazine was topped and the tempera-

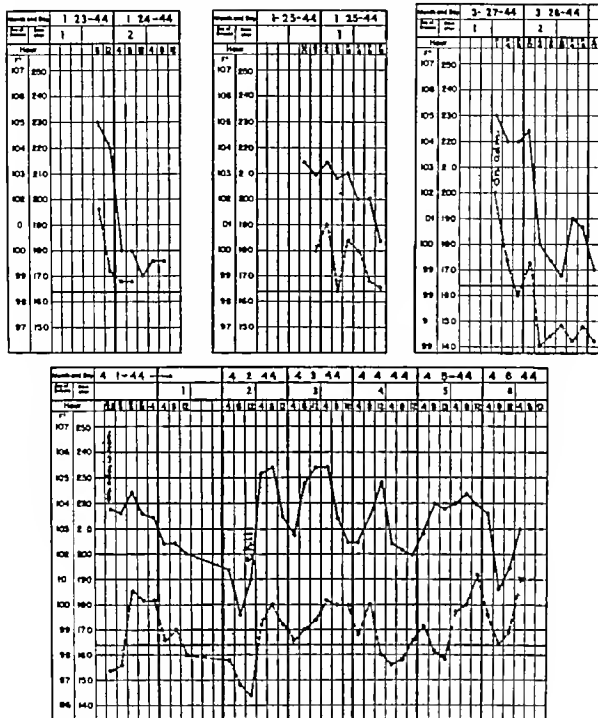


Fig 5 The first three patients show satisfactory results crisis in pneumonia. Patient in lower chart, aged 55 years, died of sudden heart failure after she had shown satisfactory improvement.

ture rose again. The x ray film showed unresolved pneumonia. At this point canavallin was started. After 3 days the temperature reached normal and remained so. The patient was discharged in good condition.

CASE 6 W M aged 32 years, with diagnosis of lobar pneumonia, pneumococcus type XXXIII was admitted to hospital January 17 1944 with a temperature of 103.3 degrees F. Canavallin was admin-

istered resulting in immediate drop in temperature to 101 degrees. Next day the temperature reached 104 degrees whereupon administration of canavallin was repeated. The temperature immediately dropped to 100 degrees. The temperature again rose to 104 degrees and the patient was given more canavallin with a temperature drop in 2 days to normal. The temperature then remained normal and the patient was discharged in good condition.

CASE 7. D. J. aged 53 years with diagnosis of lobar pneumonia, pneumococcus type IX, was admitted to hospital January 9, 1944, with temperature of 104.3 degrees. This patient was given canavalin with a temperature drop in 12 hours to 100 degrees. The patient was discharged in good condition.

CASE 8. I. W. aged 33 years with diagnosis of lobar pneumonia, pneumococcus type XII was admitted to hospital, January 27, 1944. This patient likewise was benefited by canavalin judging from the drop in temperature after its administration. This patient left the hospital against advice how ever and the final status is unknown.

CASE 9. W. W. aged 3 years with diagnosis of lobar pneumonia with septicemia. This patient was treated with sulfadiazine resulting in improvement during the first 4 days. A complication empyema developed which remained resistant to further sulfadiazine treatment. On the 15th hospital day canavalin was started by continuous slow drop intravenous method and continued for a period of 4 days. A very large amount of canavalin (300 cc.) was used. The temperature slowly became normal with clearing up of x-ray evidence of pulmonary disease.

CASE 10. R. T. aged 3 years, with diagnosis of lobar pneumonia, pneumococcus type I. This patient was given canavalin on admission with spectacular drop in temperature from 105 degrees F. to normal in 12 hours. Thereafter the patient had bouts of fever for 3 days after which the temperature remained normal. The patient was discharged in good condition.

CASE 11. A. P. aged 30 years, the diagnosis of lobar pneumonia with delirium tremens. This patient was given canavalin and sulfadiazine and symptomatic treatment for delirium tremens. Negative blood culture. The patient was discharged in good condition.

CASE 12. S. H., aged 20 years, with diagnosis of lobar pneumonia, with septicemia, pneumococcus type VIII. This patient was given canavalin on admission. Her temperature promptly dropped to normal. There was a positive blood stream infection in this case, but the patient made a good recovery and was discharged in good condition.

CASE 13. C. G. aged 60 years with diagnosis of lobar pneumonia. *Streptococcus albus*. This patient had been receiving sulfadiazine without results. Canavalin was administered by intravenous slow drop method, the patient after 3 days became conscious from a comatose condition and made slow uninterrupted recovery.

The outstanding feature of the results of treatment by canavalin of patients suffering from pneumonia was the fact that every one showed a definite drop in temperature. The temperature charts of the 3 patients showing

the most spectacular results (Cases 9, 12, 13) are not included in Figure 5 because of mechanical difficulties in showing charts covering a period of such long duration. The patient in Case 9 had empyema proved by x-ray pus was removed by paracentesis and there was a positive blood culture of type XII pneumococcus about 40 colonies per cubic centimeter of blood. The patient in Case 12 likewise had a septicemia and recovered after treatment by canavalin. The patient in Case 13 seemed to be on the point of death was delirious and comatose after canavalin therapy she became conscious and made an uninterrupted recovery.

The results of the *in vitro* experiments speak for themselves. Undoubtedly canavalin does cause death of bacteria in a proper apparatus with ideal factors. Judgment as to whether canavalin will justify its beneficial clinical promise must await further trial.

SUMMARY

A new enzymatic agent has been discovered which seems to have remarkable bactericidal properties. It has been called canavalin.

Details of the methods of isolation of the enzyme and co-enzyme which together constitute canavalin and which have the power of oxidizing polysaccharides are given.

Canavalin *in vitro* renders both gram-positive and gram-negative organisms incapable of growth.

Report of preliminary clinical studies with canavalin are included. At present this agent seems to give promise of bactericidal properties of a superior nature.

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A HELMET FOR PROTECTION AGAINST CRANIOCEREBRAL INJURIES

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THE regular issue steel helmet worn by the American soldier admittedly furnishes excellent protection against craniocerebral injuries and what is sometimes more important to the soldier has many other utilitarian advantages. However it was not designed for the use of the crews of aircraft or tanks and cannot be used to advantage by them, mainly because of its size, shape, and weight. Nevertheless, the desire of a co-pilot for protection to his head from bursting 20-millimeter Oerlikon shells led him to remove the liner of his helmet and pull on the outer steel shell over his regulation leather flying helmet. The effectiveness of this protection was emphasized by the fact that his pilot, wearing only a leather helmet was struck in the head by the fragments of an Oerlikon shell which burst between them (Fig 1). He immediately lost consciousness, developed a left hemiplegia, and a complete left homonymous hemianopsia. While the co-pilot's helmet was punctured in several places by the high velocity fragments, it afforded complete protection from even a scalp laceration.

It became obvious that members of an aircrew needed adequate protection from craniocerebral injuries. However any helmet designed for their use must meet certain specifications: (1) It must be close fitting and comfortable so that it will simulate as closely as possible an ordinary leather flying helmet and be considered a personal possession which might gather good luck like a favorite, battered felt hat. (2) It must allow free and unrestricted movements of the head in all directions, and must not interfere in any way with the field of vision. This is one of the most important objections to the use of the steel helmet pulled over a leather flying helmet. (3) It must be light in weight and afford protection from the heat and cold. (4) It must afford protection at least equal to that afforded by the regular issue steel helmet against craniocerebral injuries produced by fragmenting Oerlikon shells anti-aircraft flak or concussion due to direct blunt trauma. If these requirements can be met for aircrews the same type of helmet will serve for the use of tank crews, who at the time our study was made wore a fiber helmet which the soldier found quite un-

satisfactory for protection, efficiency or comfort.

The percentage of wounds to the head compared to its surface area to that of the body is approximately 12 per cent. It was found that the larger number of craniocerebral injuries in airmen resulted from the fragmentation of 20-millimeter Oerlikon shells, followed in turn by the larger pieces of anti-aircraft flak and concussion due to direct trauma. When an Oerlikon shell bursts it fragments into thousands of pieces which vary in weight from less than 1 milligram to 20 grams. However the largest number of effective Oerlikon shell fragments bursting in an area 5 feet in diameter and capable of causing incapacitation to the person exposed is 260. The majority of these 260 fragments weigh between 10 and 50 milligrams and their velocity varies between 400 and 600 meters per second (Fig 2).

Many materials were suggested and subjected to accurate ballistic and other tests. It was finally concluded that an acrylic resin properly manufactured offered the largest number of advantages for the purpose and most closely met the



Fig. 1. Roentgenogram of skull showing fragments of Oerlikon 20-millimeter shell embedded in the right parieto-occipital cerebral cortex.



Fig. 1. Roentgenograms of fragments from bursting 30-millimeter Derilux bell arranged according to weight. The effects (fragments range 1 right from 1 to 20 milligrams)

specifications laid down. This material of 4 millimeter thickness has a velocity resistance in relation to its weight per unit area of 440 meters per second when tested with a 52 milligram steel ball fired and photographed electrically. The velocity resistance per unit weight area of the same material of 8-millimeter thickness, similarly tested is 700 meters per second. Velocity resistance per unit weight area of 1 millimeter thickness manganese steel tested under identical circumstances varies from 400 to 600 meters per second.

The acrylic resin studied has a tensile strength of from 9,000 to 12,000 pounds per square inch. Flexural strength of 12,000 to 14,000 pounds per square inch an impact resistance of 0.1 to 0.3 foot pounds and a Brinell hardness greater than gold. It has a specific gravity of 1.10 so that it almost

floats on water and it will absorb less than 0.5 per cent of water by weight upon immersion for 7 days. It is resistant to the rays of the sun and will not soften until a temperature of between 190 and 240 degrees F. has been reached. In fact, it is one of the best nonconductors of heat and cold known to science. It smoulders if a flame is applied to it but it will not burn with an explosion and if it flames, the slightest movement extinguishes it. When hit directly the lines of shatter of this material are at right angles to the force and not directly forward as in steel. Experimental and clinical studies have shown that if pieces of it are driven into or buried in the brain or soft tissues it is inert and there is no serious tissue reaction.

A model helmet was made by heating and molding flat pieces of acrylic resin to conform to the frontal, temporal, occipital and vertex portions of the skull. These segments were hinged together snugly so that protection would not be lost and yet so that a certain pliability would be gained and a sense of a solid, bucket-like structure would be avoided. This protective helmet was then cov-

It must be remembered, but here are almost countless variations of the stages which can be reached in the manufacture of the products of an acrylic resin. The properties of the final product may vary within extremely wide limits so that one may think of it as a substitute for glass, diamonds, surgical metals or paraffin-like material. By modifying the pigment or character of the plasticizer added, the flexibility, resiliency, hardness, water and weather resistance, inflammability and ballistic properties of the material can be varied at will between very wide limits.



Fig. 3. a, left, Fabricated and segmented acrylic resin protective liner for helmet. b, protective liner within ordinary leather flying helmet.

ered with the commonly used regulation leather flying helmet and lined with chamois skin or fleece. Portions of the acrylic resin material were brought down over the ears and openings left into which earphones could be fitted. Thus afforded further protection and added the distinct advantage of the property of acrylic resin to exclude ambient noises (Fig. 3).

A helmet so constructed allows for complete movement of the head in all directions, provides complete protection over the frontal and occipital areas, and in no way interferes with the field of vision. As one molds a derby hat which may impinge slightly upon the parietal eminences and be uncomfortable so can the individual wearer mold this type of helmet by applying heat to the protective liner so that it becomes an integral and comfortable part of him. Such a model helmet

constructed of acrylic resin 4 millimeters in thickness covered and lined as described weighs 18 ounces and if 8-millimeter thickness material is used thus affording more protection per unit weight area the total weight of the helmet is raised to 27 ounces. The steel body of the regulation helmet weighs 35.84 ounces. The use of an acrylic resin product obviates the necessity of using steel with its high priority demands for other purposes and provides a less expensive material which can be fabricated quickly and without the expensive manufacturing accessories.

The extension of the use of this same material in the form of panels which can be easily inserted into and removed from an airman's protective clothing and thus provide lightweight body armor for protection against chest, abdominal and extremity injuries is logical.

SURGERY OF THE PELVIC COLON AND RECTUM

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WITH the co-operation of our tumor clinic we have classified those patients treated the past seven years at the Mason Clinic for surgical lesions of the colon and rectum. These lesions have been subdivided into those of (1) the right colon (2) the transverse colon (3) the left colon, including the upper sigmoid and (4) the pelvic colon i.e., the lower sigmoid and rectum. This report will be confined to the fourth group. The lower sigmoid is grouped with the rectosigmoid because in each instance resection required either permanent colostomy or the single alternative of rectocolic anastomosis deep in the pelvis—a technically difficult if not hazardous procedure. That portion of the redundant or upper sigmoid which permits of exteriorization resection is not included in this report.

Of 195 patients, 111 had lesions of the pelvic colon or rectum (Table I). Ninety-nine of the 111 were carcinoma, while 12 required major surgery for lesions other than carcinoma. An analysis of these 12 is tabulated in Table II.

NON-SPECIFIC GRANULOMAS

Stenosing inflammatory granulomas may cause complete obstruction of the colon and may be grossly indistinguishable from cancer even after the abdomen is opened. There were 4 instances of this in the pelvic colon. 2 required a combined resection while in 2 an anterior resection with anastomosis was done. In each of these (Figs. 1 and 2) because of fever and extensive local fixation at the rectosigmoid the resection was accomplished in 2 stages. In each the resection was difficult despite marked recession of the tumor between stages and in each stenosis was practically complete, and in 3 of the 4 the true diagnosis was unpredicted before histological examination. The etiology in these 3 remains undetermined. A Frei antigen test for granuloma venereum was negative in 2 there were associated diverticula. In a 4th case a sleeve of lower sigmoid had become directly involved from contact with a prolapsed loop of terminal ileitis. And this hose-like sleeve of colon had to be resected secondarily after resection of the terminal

ileum and cecum. Parenthetically this patient made a complete recovery was commissioned a captain in the army and died in action in the battle of Tunisia.

Diverticulitis as a cause for stenosis of a sleeve of colon is well recognized. However the fact that cancer may occur simultaneously with diverticula may not be as well appreciated. Such was the case in 1 man aged 75 years, diagnosed elsewhere just before admission to the hospital as diverticulitis (Fig. 3) and given only medical recommendations. At operation a large local cancer involving this portion of the lower sigmoid, and adherent to one loop of small bowel (Figs. 4 and 5) was found. A one stage resection of small and large bowel with small and large bowel primary anastomosis was accomplished, the patient being discharged from the hospital after 18 days.

OBSTRUCTING ENDOMETRIOMA

There were 3 cases in which an endometrioma obstructed the lower sigmoid. In one of these an anterior resection with anastomosis was accomplished, and in the other 2 temporary colostomy and resection of the ovaries was done.

CARCINOMA OF PELVIC COLON

There were 99 patients with cancer of the pelvic colon who came to surgery (Table III). Surgical assistance was limited to palliative colostomy in 31 of these, while in 6 the lesion was too advanced to justify even this. Two were given palliative relief from bleeding by diathermization. Three others were cured by diathermization. This leaves 67 whose lesions were resected surgically of this group 5 already had distant metastases. Excluding the 3 who had curative diathermization, and including 3 moribund patients not operated upon the *resectability* in the series was therefore 66 per cent.¹ The surgical mortality was 5 per cent overall, 3.8 per cent for those resected.

The follow up on the majority is too short to be of value. Of the 49 combined resections 7 (14 per cent) have died of metastases, 4 of unrelated causes, and 2 cannot be followed. 73 per cent are known to be living and well. Of the 7 posterior resections 4 are known to have died of carcinoma, and 2 cannot be followed. The compromising in-

¹None who refused operation or went elsewhere are not included.

From the Department of Surgery, The Mason Clinic. Delivered before the North Pacific Surgical Society at its annual meeting, Vancouver, B. C. November 30, 1943.

All operations in this review were performed by either Dr. E. B. Porter, C. S. Stone, J. or the author.

adequacy of the posterior resection is now felt by all workers in this field. The anterior resections have all been done within the past 15 months all but 1 are living. The patient who died and 3 others, had hepatic metastasis at the time of resection.

PLACE OF DIATHERMIZATION

Diathermization is a compromising procedure. It does not remove nor does it permit examination of the regional lymphatics. However if one has the proper equipment and understands its limitations, diathermization is a valuable aid in managing a small minority of patients. It allays bleeding, cleans the infected sloughing surface of the ulcer and may be attended by temporary clinical improvement in strength and well being. In 1 patient, age 81 years feeble, bleeding and toxic, the improvement after 6 weeks was so great that he successfully underwent a combined Miles resection (Fig 6). Histologically his growth was a colloid adenocarcinoma (Fig 7) and this may explain the fact that it did not completely recede with diathermization—and hence the necessity for a combined resection. In 3 patients, in their 8th decade of life all obese and feeble, with proctoscopically accessible lesions varying in size from 1.5 inches to 2.5 inches in diameter surgical diathermization was substituted for surgical resection. One of these lived 5 years and died of a broken hip, another 6 years and died of acute coronary thrombosis—each without evidence of local recurrence or metastasis. The 3rd is living and well 3 years since treatment and without evidence of carcinoma.

We therefore feel that the procedure justifies consideration in certain patients whose lesions are technically accessible and who are adjudged to be hopeless surgical risks. Preservation of normal bowel continuity is not a justification for its use.

TABLE I—SURGICAL LESIONS OF COLON
MASON CLINIC

(1936-1943)	N patients	N operations	Patient mortality
Site of lesion			
Right colon	13-15*	47	
Transverse colon	8		
Descending colon (including upper sigmoid)	43-1*	7	8-4 of 8†
Pelvic colon and rectum	— 5*	66	5- of 5†
Total	64	120	4-6 of 5

*Patients having surgical lesions other than cancer
†Deaths following palliative colectomy only

THE COMBINED RESECTION

It is our experience that this must be considered the preferable surgical attack both from the standpoint of surgical mortality and the theoretical eradication of the maximum of local tissue environment and regional lymphatics. The only disadvantage is the loss of anorectal function which loss is well compensated by the high percentage of cure being reported from all authors engaged in this special work. The reported mortality is being steadily reduced.

It should be remembered that lesions arising in the pectinate line may be adenocarcinoma (Fig 8) or more rarely epidermoid carcinoma (Fig 9). The inguinal lymphatics should be carefully examined for metastasis in lesions arising this low. Unfortunately some may seek advice too late (Fig 10).

Of 49 combined resections for primary carcinoma and including an additional 3 for other lesions, there was but 1 hospital death. It is with hesitancy that we mention this low mortality because of the limited size of the series. Interestingly enough it was not our first but the 49th of the series of 52 who died. The patient aged 66

TABLE II—PELVIC COLON—SURGICAL LESIONS OTHER THAN CANCER

No. of pt.	Pathological lesion	Operation	Deaths
4	Scrooping granuloma	{ Combined abdominoperineal Anterior resection with anastomosis	
	Ovarian carcinoma recurrent in rectum	Combined abdominoperineal	
	Bleeding polyp lower sigmoid	Sigmoidectomy	
	Obstructing endometrioma	{ anterior resection with anastomosis Temporary colectomy and resection of ovaries	
	Proctoscopic perforation	Laparotomy closure	
	Acute suppurative diverticulitis	Temporary defunctioning colectomy	
	Surgical fistula during prostatectomy	Temporary colectomy	



Fig. 1



Fig. 2



Fig. 3

Figure 1. The growth of the tumor was a mass of one to three centimeters in diameter. The tumor was removed by a colostomy. The tumor was removed by a colostomy. The tumor was removed by a colostomy.

Figure 2. The growth of the tumor was a mass of one to three centimeters in diameter. The tumor was removed by a colostomy. The tumor was removed by a colostomy. The tumor was removed by a colostomy.

ve re, had been out at least 4 days. Suddenly he th on the 10th post operative day was judged finally a due to pulmonary embolism. Age of those resected varied from 21 to 8 years.

The procedure as first advocated by Miles (1) is well standardized, however various authors have contributed minor variations in technique and after-care which have been helpful. Some of these literature reports adaptable to one surgeon while others appeal to another. Perhaps therefore we should mention our preferences—although the fact that in this brief experience we have come to favor certain modifications and to discard others does not imply that the method should prove true in other hands.

1. As a working rule we prefer the 1 stage procedure as advocated by Miles. Of the 52 cases, only 13 were accomplished in 2 stages. Advanced obstruction not relieved adequately by cecostomy or a fecal course secondary to superimposed local infection constitute in our opinion the only contraindication to a one stage resection. Advanced age and unpaired surgical risk are not indications for putting the patient through a

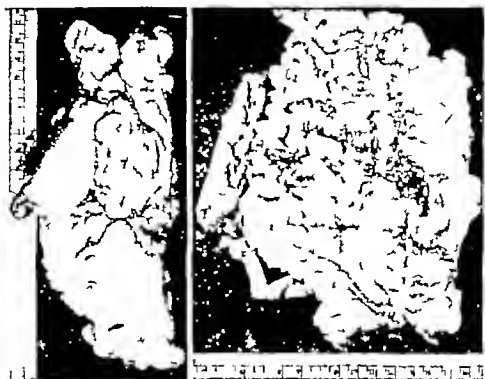
operation to accomplish what can be accomplished with greater technical ease in one.

2. General inhalation anesthesia is preferred.

3. A lower midline or lower left rectus splitting incision is made with the permanent colostomy to be made through a separate carefully placed left lower gridiron incision.

To prevent skin stricture Miles modified his original technique by removing an oval of skin about the colostomy. We have had 5 skin strictures despite this, but feel that this modification reduces the incidence of stricture. Because of 2 lateral festulas in the colostomy stump secondary to perforation of the everted bowel by the sharp edge of the external oblique aponeurosis, we now also remove a *elliptical wedge of this fascia* on either side of the colon. In addition we carefully visualize each layer as the incision is made rather than trust to the quicker blind stab. The opening in the left lateral gutter between the mesentery and the abdominal parietes is closed to prevent volvulus of the small gut.

4. The perineal wound is packed open with a rubber dam into which gauze is loosely placed. For



Figs. 4 and 5. An exterior and interior view of the involved sleeve of sigmoid shown roentgenologically in Figure 3. It is to be noted that this annular ulcerative adenocarcinoma has invaded a loop of small bowel which was resected *en bloc* with the sigmoid. Double primary intestinal anastomosis was done.

faster healing it is important to build as redundant a pelvic peritoneal diaphragm as possible. In the male this is accomplished with greater ease by freeing the peritoneum from the bladder. After the pack is removed irrigation with an emulsion of sulfacarbamide seems to speed third intention healing. It is beneficial to get the patient out of bed early—in 6 or 7 days if possible.

5 We have not used sulfasulidine or sulfaguanidine in preparation for the combined operation but we do use now a combination of sulfathiazole and sulfanilamide microcrystals locally between the omentum and the parietal peritoneum and in the abdominal and perineal wounds.

6 A blood transfusion is given routinely during the operation and multiple transfusions if the patient is anemic. Vitamin C and B complex are given parenterally, although the administration of the B complex is delayed for 5 days after operation so that it will not inhibit the action of the sulfa drug.

7 The colostomy clamp is removed at the end of 24 hours to leave it longer may accentuate the abdominal distention and could favor separation of the peritoneal adherence around the colon. A dry gauze collared around the exteriorized colostomy stump at the time of operation is left for from 4 to 5 days as a safeguard against retraction of the colon.

8 The duration of life for 3 years or more, in a few patients with hepatic metastasis has encouraged us to resect some lesions despite one or two distant metastases. It has also been consoling to cite these instances in reporting such involvement to the patient or his family. It should also be mentioned that in 2 proven instances what we had adjudged by palpation at operation to be a solitary hepatic metastasis proved to be a solitary congenital cyst near the surface of the liver (Fig. 11). In each of these instances a radical resection was performed and autopsy following unrelated death (postoperative embolus perforated gastric ulcer) later proved the fallacy of the operative impression.

TABLE III—CANCER OF PELVIC COLON AND RECTUM

No. of pt.	Type of operation	Patient mortality
	Palliative colectomy	(cachexia)
6	Exploration only	
	Palliative colostomy	
3	Curettage colostomy	
9	Combined abdominoperineal resection	(embolus)
67	Colectomy and posterior resection	
7	Anterior resection with anastomosis	(embolus)
9	Anterior resection with anastomosis	(heart)
1	Anterior resection with colostomy	
99		3 (3.0%)



Fig. 6. Photograph of colloid adenocarcinoma resected by the combined approach in man aged 8 years. In this previous resection he had several applications of diathermy to the ulcer.

This certainly should be borne in mind before a radical resection is withheld in the face of what is thought to be a hepatic metastasis.

9. We have been pleasantly surprised with the ability of some of these patients to withstand ex-



Fig. 8. Photograph of an adenocarcinoma of the sphincteric region of the anus. There is no demonstrable inguinal lymphatic metastasis.

tensive resections of what at first appeared to be a locally inoperable growth.

In 1 patient a coincident (Fig. 12) cystadenocarcinoma of the ovary was grown to the sigmoid and was therefore resected *en bloc* along with the cancer of the rectum. In this series 2 patients had associated cancer of the ovary, 2 had had cancer of the breast, and 1 had had cancer of the uterine fundus.

One of the most hazardous was this case (Fig. 13) in which a 4 months fever and anemia from superimposed infection persisted for 6 weeks after a first stage Lahey colostomy. At the second stage resection of a loop of adherent ileum was required as a preliminary to the combined removal of the rectum, and freeing the local growth with a margin was difficult. As is often true, the most difficult in the amphitheater runs the smooth exit convalescence—thus affording a stimulus to increasingly broader resectability.

MUCOSAL POLYPS

There were 2 instances of single, large, pedunculated polyps just above the rectosigmoid (Fig. 14) which were inaccessible via the sigmoidoscope. The advantage of contrast media in roent-

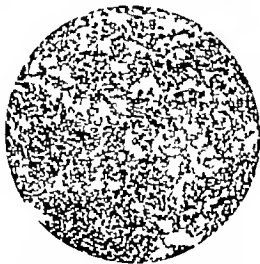


Fig. 7. Photomicrograph of the lesion shown in Figure 6. The signet ring cells are easily seen.



Fig 9a. Photograph of an epidermoid carcinoma of the sphincteric region of the anus. Bilaterally enlarged inguinal lymph nodes led to a bilateral radical resection of the inguinal lymphatics, but no positive nodes were found.

genological diagnosis of these is recognized. One of these was removed by one stage abdominal sigmoidectomy with simple closure of the gut, the other by colostomy and subsequent closure in 2 stages. During this same period there were 68 patients (not included in the statistical table) with one or more polyps which were removed and the rectum diathermized through the sigmoidoscope. Ten of these 68 showed hyperplasia at the tip graded as adenocarcinoma grade I.¹

The malignant potentiality of all colonic mucosal polyps is now recognized. In this series of 159 malignant neoplasms there are 6 instances of double malignant lesions of the colon and one of a triple malignant lesion. In several lesions there were satellite benign polyps (Fig 15).

When the polyp showing borderline malignant hyperplasia has a long benign pedicle, or when a small sessile polyp without definite malignant change is without ulceration or palpable indurated invasion, we have been satisfied with marginal removal and diathermization via the proctoscope. Of the 10 showing borderline malignant changes so treated, 2 did not return and the other 8 have shown no trace of recurrence.

¹Since this review was delivered, another case has now been in the hospital. This case clearly illustrates the malignant potentiality of mucosal polyps. This man, aged 60 years, was examined in the clinic 5 years ago, at which time an incidental finding was mucosal polyp, two-thirds in diameter seated in the rectal ampulla. He was to return the following week for removal of the polyp and diathermization. He did not return until 5 years later. At which time he is found to have an adenocarcinoma at the exact site at which the polyp was previously described.



Fig 10. Photograph of an inoperable adenocarcinoma of the anus with extensive involvement of the buttocks.

It should be emphatically repeated however that the invasive polypoid lesion with or without ulceration requires radical resection of the gut and its regional lymphatics. The smaller or earlier the lesion, the more the reason for a wide resection as these patients afford the greater opportunity for cure. Figure 16 is a photograph of the smallest lesion we have been required to resect radically. In another instance of a large sized benign polyp requiring laparotomy for removal, it was thought preferable to resect the sleeve of gut rather than simply to remove the polyp.

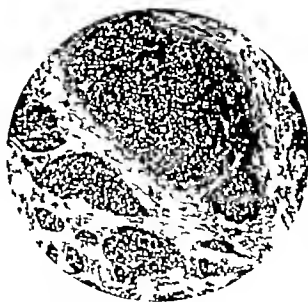


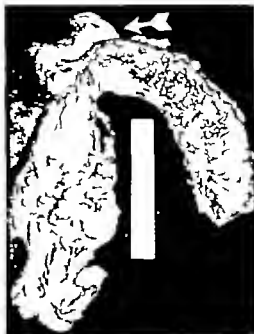
Fig 9b. Photomicrograph of lesion in Figure 9a.



Fig

Fig Photograph of congenital solitary cyst of the liver which at the time of surgical exploration was thought by palpation to be hepatic metastasis. This possibility should be born in mind at the time of exploration. This patient died 3 years after surgical resection from an unrelated cause and the specimen was photographed before autopsy.

Fig Photograph of carcinoma of the rectum (lower arrow) associated with coincident carcinoma of the ovary which has secondarily invaded the rectosigmoid (upper arrow).



Fig



Fig 3 Interior and exterior photograph of an extraluminal carcinoma of the rectosigmoid with secondary invasion of loop of small bowel. A preoperative febrile course which did not subside following first stage colostomy is explained by the degeneration and superimposed infection, which are visible in the growth.

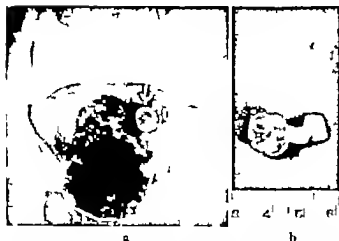


Fig. 14. a, Roentgenogram with contrast media depicting a solitary polyp of the sigmoid. b, Photograph of the same polyp after removal by one stage sigmoidectomy. c, Photomicrograph of the same lesion.



Fig. 14c.



Fig. 15. left. Adenocarcinoma of the ampulla of the rectum associated with multiple satellite benign polyps (arrows).



Fig. 16. Photograph of the smallest adenocarcinoma for which we have performed a proctosigmoidectomy (Lateral view of the opened rectum—see arrow).

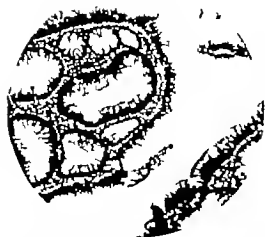


Fig. 7 a, left. Preoperative biopsy of sessile polypoid rectal lesion. Such shows no evidence of malignancy.



b, Photomicrograph of the same lesion after removal showing adenocarcinoma.

A case specifically illustrating this differential problem is that of an attractive 31 year old wife who had a sessile polypoid lesion, 3 centimeters in diameter in the upper ampulla. Three biopsies failed to show malignancy (Fig. 17a). Despite this fact and because of its grossly invasive appearance, we elected—against the advice of some

—to resect radically this bowel and its regional lymphatics (Fig. 18). Because this patient was thin and with a large true pelvis, we were able to accomplish an exceptionally low primary anastomosis and thereby preserve bowel continuity. The responsibility in such a disputed case of needlessly sacrificing rectal function is second only to the responsibility of sacrificing life either from inadequate resection of cancer or from a surgical mortality in a technically hazardous procedure. The removed specimen showed cancer (Fig. 17b).

On the other hand, a benign lesion which may be mistaken for an invading sessile cancer is the submucosal lymphoid tumor referred to as a "rectal tonsil." In one young lady the disc-shaped tumor was 3 centimeters in diameter and 1 centimeter in thickness and before biopsy revealed its true nature, it was thought to be malignant.

ANTERIOR RESECTION OF THE PELVIC COLON WITH PRIMARY ANASTOMOSIS

Miles in 1908 published his conception of the lymphatic spread of cancer of the rectum upward, downward and laterally. Supported by his excellent results with the combined operation this won universal adoption to the point that anything less radical has come to be considered a compromising procedure. However, Westhaus recently has taken issue with Miles as to the downward lymphatic spread. In 101 operative specimens removed by radical abdominal perineal resection he found 210 metastatic nodules. Only one of these was located below the level of the lower edge of the growth. Collier and associates and Gilchrist



Fig. 8. Photograph of the gross lesion shown in Fig. 7.

and David have also made studies indicating that lymphatic metastasis is upward in the great majority of instances. *It would seem probable that the spread is downward only when extensive lymphatic involvement blockades the upward path.* If this is true then it would seem that certain low sigmoidal and rectosigmoidal lesions may be adequately resected without sacrificing continuity of the lower bowel.

Since the procedure of primarily anastomosing the colon this low in the pelvis is technically difficult, and because many authors still question its adequacy, we were loath to use it until recently. The first two trials were in patients with several metastatic areas in the liver. We have now performed 9 anterior abdominal resections of the pelvic colon with one stage primary anastomosis of the sigmoid to the rectal ampulla. Four of these were palliative resections. There was 1 death—this from a pulmonary embolus (verified by autopsy) on the 14th day in an otherwise uncomplicated course, the wound having healed *per primam* without fistula, the source of the embolus proving to be an acute thrombosis of superficial varicose veins in the right leg.

In 2 additional poor risk patients anterior resection was supplemented by closing the ampulla and bringing out the proximal bowel including the tumor as a permanent colostomy. In 1 of these patients, short of stature and weighing 275 pounds, an anastomosis would have been definitely hazardous in the other because of extensive lymphatic metastasis the left colic artery had to be resected and hence the entire descending and pelvic colon and it was deemed inadvisable to prolong the operation further by anastomosis. This patient died on the 7th postoperative day the cause of death being undetermined. In a 12th patient who had an obstructing endometrioma the rectosigmoid was resected and anastomosis was done in stages after a defunctioning temporary ileostomy.

In this brief experience we have found no surgical objection to anastomosing the pelvic colon. It is difficult in a small pelvis it requires the same time as the combined operation, but the hospitalization period is shortened as compared with the combined operation. We have tried the closed and open technique and prefer the latter. Such anastomosis should not be attempted in the obstructed bowel without preliminary surgical defunction. Here as in any intestinal anastomosis peritonitis and death are not so likely from operative soiling as from subsequent leakage in an inaccurate anastomosis. In 4 instances concomitant tube cecostomy was performed. These have closed

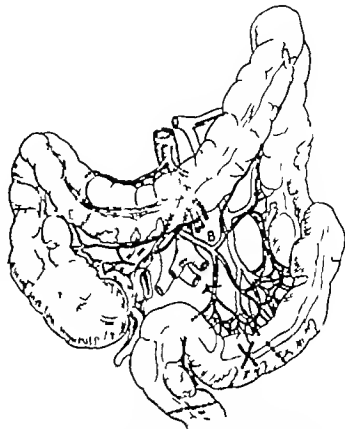


Fig. 19. Diagrammatic showing of the circulation of the colon. "X" marks the zone wherein one must be careful to insure adequate circulation of the end of the sigmoid if a rectosigmoid anastomosis is done.

spontaneously without prolonging hospitalization or causing inconvenience to the patient, but their course has seemed no smoother than that of those in which it was not done. Nor has a rectal tube been used beyond the anastomosis. Usually the anastomosis is sufficiently low that a rectal finger can be used to explore beyond it or pass a tube if this should prove to advantage post-operatively. A hard tube at the anastomosis might serve rather to obstruct the lumen and impair healing in a colon which has not been defunctioned. Obviously this series is too small for conclusions to be drawn.

Regardless of how short the cuff of remaining ampulla, one need not worry about its blood supply as the middle and inferior hemorrhoidal artery or even the latter alone, apparently suffices to supply this segment. But this is not true of the proximal end. Radical resection just as in the combined operation requires section of the superior hemorrhoidal vessels; this leaves a danger zone between this level and that supplied by the sigmoidal arteries (Fig. 19). One of the technical niceties of the procedure is freeing the gut ends of fat to permit accurate sutures without sacrificing

the terminal arterial supply and this seems better accomplished in the open technique. In the closed technique the Harvey Stone or the McClure Furniss clamps are most helpful.

It should be remembered that the ampulla, having no serosal investment is slow to heal. Because of this, secondary leakage may be expected and planned for. We build a peritoneal diaphragm about the anastomosis, and a Penrose drain is left behind the anastomosis in the presacral area. Four of the 9 developed temporary fecal fistulas, none showed evidence of peritonitis, and in all the fistulas healed spontaneously in from 2 to 8 weeks. The patient was not kept in the hospital additional time because of the fistula.

One patient had periods of diarrhea attributed to narrowing at the anastomosis. However a rectal finger passes the anastomosis easily. This patient, aged 68 years, required resection and anastomosis of the small and large bowel and hysterectomy (because of local extension)—all accomplished in one stage. Despite the occasional diar-

rhea she has gained 26 pounds in weight and is otherwise symptomfree.

SUMMARY

1. An analytical review of 111 patients requiring major surgery for lesions of the pelvic colon is presented. Ninety nine of these were carcinoma.

2. Resectability of the malignant lesion was 66 per cent. overall hospital mortality 5 per cent.

3. The combined resection was the most commonly applied, although in the past 18 months some anterior radical resections with primary anastomosis have been done.

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AN EXPERIMENTAL AND CLINICAL STUDY ON THE USE OF ADULT ANIMAL TISSUE EXTRACT IN THE ACCELERATION OF WOUND HEALING

A Preliminary Report

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IT is well known that the organism, from the lowest form of life to the most complex has the power of tissue repair a cycle of events beginning with injury and ceasing when the reparative processes are completed. In man the ability of an open wound to heal with organ specific tissue is a remarkable example of this fundamental law of biology. It has long been suspected that in all tissue there are two important mechanisms concerned with repair namely growth inhibiting and growth promoting factors. It is with the latter that this communication primarily deals, particularly in its practical application to wound healing—an ever current problem to the surgeon.

REVIEW

In 1925 Baker and Carrel (1) reported that embryo-web porridge was effective in accelerating wound healing both *in vivo* and *in vitro* and following this Fischer produced an embryonic extract which stimulated growth *in vitro* and was apparently successful when used in animals and man.

From 1925 to 1932 other workers (2, 3, 14, 17, 19, 20, 22) demonstrated the growth accelerating effect of embryonic juices on wounds, but because of its impracticability this method of treating wounds was little used. Interest however was revived in 1939 and 1940 when Fischer prepared a modified desiccated embryonic extract which was used in animal experiments by Nielsen and clinically by Waugh.

Prior to 1939 growth promoting substances were prepared primarily from embryonic tissue because it was felt that such factors which might promote growth would be present in greater amounts although extracts of tissues and organs of adult animals had occasionally been used as constituents of tissue culture media. In these cases extracts from mitotically active or neoplas-

tic tissues, such as bone marrow and tumors, were used. However the growth promoting activity of these extracts was always regarded as much less than that of embryonic extract (15, 16, 21).

In 1939 it was shown by Hoffman and Doljan (11) that extracts of tissues and organs of adult fowl increased the growth rate of chicken fibroblasts *in vitro* to a remarkable extent completely independent of the degree of differentiation of the tissue which was extracted. It was found that most activity was present in brain, heart and smooth muscle all of which are stable adult tissues (12, 13). It was further shown that adult tissue extract from chickens had a greater stimulating effect on the growth of chicken fibroblasts than did embryonic extracts. In a series of experiments comparing the cell growth stimulating action of aqueous extracts of heart (adult) tissue it was shown that the former had a growth promoting effect about three times as great as that of embryonic extract. This effect was not found to be transitory as previously believed since tissues may be cultivated indefinitely in media containing adult extracts (5). Also it was shown that the growth promoting action of adult tissue juices is not species specific inasmuch as extracts of heart muscle of calf, sheep, rabbit and dog had a cell growth promoting effect of the same order and magnitude on chicken fibroblasts as homologous tissue extract. Finally it was found (6) that explanted human epithelium *in vitro* had a growth about 16 times as great when adult chicken heart extract was added to the usual protective media (plasma and Tyrode solution). This fact and for the reasons that it is more stable and more easily obtainable suggested that adult tissue extract might be of value in promoting growth of tissue in human wounds. Schloss¹ working at the Hadassah Hospital in Jerusalem in 1942 used adult tissue extract in the treatment of indolent human wounds with encouraging results, and it was further to try this

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²Personal communication.